Shaping Ships for People: Human Centred Design Knowledge into Maritime Education

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Declarations

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Apsara Abeysiriwardhane

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# Abstract

The ship design process focuses primarily on the technical aspects of engineering specifications and regulatory requirements derived from classification societies and flag states. There is often little or no attention paid by designers to the operational demands of onboard crew and the detailed design characteristics of the work environment of a ship. As a result, inadequate Human Factor (HF) consideration in ship design is a common contributory cause to maritime accidents. In fact, there is an increasing awareness in the marine industry that HF needs to be considered in ship design through a Human Centred Design (HCD) approach. Current maritime education however is heavily biased towards the technical aspects of design, limiting the education of students in HF, HCD and onboard operational issues. This has made it difficult to convey the significance of HCD and a usability mind-set to designers. An early intervention in the maritime design education is thus essential.

This research study constructed a pedagogical framework for integrating HCD knowledge into maritime education through undergraduate design projects. Within this framework, Peer-Led Team Learning (PLTL) pedagogy was linked to design project unit driven by Problem-Based Learning (PBL) pedagogy in conjunction with Vygotsky's Zone of Proximal Development (ZPD) theory and the scaffolding concept. HCD knowledge was then disseminated through this framework over two consecutive years, and then evaluated for effectiveness, as well as validated through an Action Research methodology. Maritime design undergraduates undertaking yearlong PBL-based design projects at the Australian Maritime College participated in this study.

The findings present the effectiveness of this teaching framework for imparting non-technical HCD knowledge to technically-oriented maritime design project unit. The total effort made a noteworthy contribution to improving the HCD understanding of 56 of the undergraduates out of 69 to a satisfactory level, from an original point of a lack of understanding. In addition, as a result of adopting a peer-leader approach, this study created a cohort of unique HCD champions who are now trained to carry forward their knowledge into future design teams, thus guiding them to shape ships for people.

Furthermore, the findings show the benefit of using multiple approaches, such as conducting HF-related onboard activities, organising guest lectures, conducting discussions, and using virtual tours of ships, pictures, videos and real-world examples of HF, in order to meaningfully impart HCD knowledge. Such approaches incentivised the engineering students, as they can be categorised as 'demanding' in terms of learning preferences and their learning styles are diverse; visual, sensing, inductive, active, and global. This shows that in order to effectively transfer HCD knowledge into engineering education, these learning preferences should become partner to the traditional linguistic dimension of teaching, process which includes verbal, symbolic, and numerical representations.

Future research may advance this pedagogical framework and the HCD knowledge dissemination activities by way of implementation in other maritime institutes who deliver PBL-based maritime design projects. However, in order to meaningfully implement this 'bottom-up' initiative, the acknowledgement of maritime institutions towards the significance of HCD knowledge for their undergraduates is pivotal.

Keywords: Maritime, Naval Architecture, Ship Design, Human Factors, Human Centred Design, Maritime Designer, Maritime Education, Knowledge Dissemination, Scaffolding, Champion

List of publications

Peer-reviewed and published scientific journal articles

Abeysiriwardhane, A., Lützhöft, M., & Enshaei, H. (2014). Human Factors for Ship Design; Exploring the Bottom Rung. *Transactions of the Royal Institution of Naval Architects Part C1: International Journal of Marine Design, 156*(1), 153-159.

Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S., & Enshaei, H. (2015). Investigate and Stimulate Future Maritime Designers' Context of Use Knowledge: A Workshop Approach. *Transactions of the Royal Institution of Naval Architects Part C1: International Journal of Marine Design, 157*, 179-193.

Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S., & Enshaei, H. (2016). Human Centred Design Knowledge into Maritime Engineering Education; Theoretical Framework. *Australasian Journal of Engineering Education*, 21(2), 49-60, DOI:10.1080/22054952.2017.1287038

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Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S., & Enshaei, H. (2016). *Incorporate Good Practice into Ship Design Process; Future Ship Designers Meet End Users*. Paper presented at the ERGOSHIP 2016: Shaping Shipping for People Melbourne, Australia, 6-7 April.

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Additional relevant publications

Peer-reviewed conference proceeding

Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S., & Enshaei, H. (2015). *Future Ship Designers and Context of Use; Setting the Stage for Human Centred Design*. Paper presented at the International Conference on Marine Design 2015, London, UK, 2-3 September.

Peer-reviewed book chapter

Lützhöft, M., Petersen, E. S., & Abeysiriwardhane, A. (2017). The Psychology of Ship Architecture and Design. In M. MacLachlan (Ed.), *Maritime Psychology: Research in Organisational and Health Behavior at Sea* (1 ed.). Switzerland: Springer.

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List of abbreviations

ABS	American Bureau of Shipping
AMC	Australian Maritime College
AR	Action Research
CyClaDes	Crew-centred Design and Operation of ships and ship systems
CoU	Context of Use
EBDIG	The European Boat Design Innovation Group
HCD	Human Centred Design
HF	Human Factors
HSC	High Speed Craft
GA	General Arrangement
ICS	International Chamber of Shipping
IEA	International Ergonomic Association
IMO	International Maritime Organisation
ISO	International Organisation for Standardisation
LR	Lloyd’s Register
MLC	Maritime Labour Convention
NAE	United States National Academy of Engineering
NI	The Nautical Institute
PBL	Problem-Based Learning
PLTL	Peer-Led Team Learning
SOLAS	The International Convention for the Safety of Life at Sea
STCW	The International Convention on Standards of Training Certification & Watchkeeping
UCD	User Centred Design
ZPD	Zone of Proximal Development
2D	Two-Dimensional
3D	Three-Dimensional

Chapter 1
Introduction

This chapter comprises an introduction to the problem addressed in this research study, which is followed by the research aim, structure of the dissertation, an explanation of the use of ‘I’, limitations of the research, and brief summary of academic papers.

1.1 Problem outline

The maritime industry is growing daily in terms of technology, regulations, capacity and safety. Nevertheless, there are still a significant number of accidents that occur at sea. It has been estimated that 60-80% of all casualties at sea are the result of operator error (Card et al., 2005; McCafferty & Baker, 2006). For decades, the maritime industry has held a belief that technology and regulations will address these maritime safety concerns. This partly contradicts analysis done by Allianz Global Corporate and Specialty (2016) and the International Union of Marine Insurance (2016), along with the aid of Lloyd's List casualty statistics. The analysis for the period of 2001-2016 revealed that insurance claims over US$10 million have shown a growth even though total ship losses are declining. Furthermore, when analysing the underlying causes for the operator errors, many of them are linked with Human Factors (HF)/Ergonomics (E) [1] issues, which in turn can be traced back to the shortcomings of designs (Earthy & Sherwood Jones, 2010; Lundh, 2010; Lützhöft, 2004; Lützhöft et al., 2011; Rasmussen, 2005; Rothblum, 2000; Squire, 2007; Strong, 2000; Walker, 2011).

As an example, 66 deaths in British shipping in 2003-2012 (Roberts et al., 2014) were analysed from an ergonomics perspective and it was found that in 64% of the cases (42 people), the fatalities could have been avoided by considering HF in the early design stage (Sherwood Jones, 2016). The main contributors are well known in shipping; slips, trips, falls in mooring and enclosed spaces (Sherwood Jones, 2016). Therefore, the early stages of ship design present under-utilised opportunities to 'design the problem out' instead of 'adapting the users to the design' (Rothblum, 2000). This should reduce design-induced errors, work-around and retrofit costs. In fact, there is a growing awareness in the marine industry that HF needs to be considered in ship design through a Human Centred Design (HCD)[2] approach. By applying the HCD approach, designs should be made more 'usable and useful by focusing on the users, their needs and requirements' (ISO, 2010), consequently optimising 'human well-being and overall system performance' (IEA, 2016). Numerous studies in the maritime domain discuss the systemic benefits of imparting HCD knowledge into the design and build process (Costa, 2016; Dobie, 2003; Earthy & Sherwood Jones, 2006; Earthy et al., 2010; Lundh, 2010; Lützhöft, 2004; Lützhöft et al., 2007; Petersen, 2012; Pomeroy & Sherwood Jones, 2002; Rasmussen, 2005; Sherwood Jones, 2005b; The Nautical Institute, 2015).

Some of the stakeholders who are responsible for integrating HCD into the ship design process are ship designers, regulators, ship managers, administrators, shipbuilders, ship operators, technical managers, ship surveyors and ship inspectors (LR, 2014; Rasmussen, 2005). While each of these stakeholders may contribute to HCD integration, the degree of influence that maritime designers have on the design process is greater than any other stakeholder, since design work has mainly been executed by them. Therefore, it can be expected that raising the designers' HCD understanding would be influential. To support this, some maritime HF specialists and organisations have already taken steps to raise designers' awareness and understanding of HF and HCD (CyClaDes, 2014; Earthy et al., 2006, 2010; EBDIG, 2014; LR, 2014; Lützhöft, Petersen, et al., 2017; Mallam, 2016; NI, 2015a; Sherwood Jones, 2005b; The Nautical Institute, 2015). However, maritime designers' education tends

[1] HF/E refers to: 'the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimise human well-being and overall system performance' (IEA, 2016)

[2] HCD refers to: 'an approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying HF/E and usability knowledge and techniques' (ISO, 2010)

to focus on the technical aspects of design more than the end-user requirements, which has made it difficult to convey the significance of HCD and usability mind-set to designers (Kuo & Houison-Craufurd, 2000; Myles, 2016; Petersen, 2012; Walker, 2011).

To this scarcity of academic work, I add my personal experience as a naval architect. I have worked as a naval architect for several years in a reputed ship design and consultancy firm in a country where ship design and the maritime industry make a substantial contribution to their economy. Throughout my career, which was challenging and innovative every day, I was involved in a number of design projects, such as double hull conversions, modifications, and new-build designs for various clients all over the world. The design process I followed mainly consisted of developing requirements, conducting analyses, developing drawings, building electronic models and writing specifications. This long and iterative process was divided into phases, including concept design, preliminary design, contract design and detailed design, following the traditional ship design spiral (Evans, 1959; Eyres, 2001). Usually the process started with a mission statement, that is, what type of vessel needed to be built to carry how much of which particular cargoes in/to what area of the world. The further this process proceeded, the more detail was needed, for instance, in the dimensions of the vessel, hull design, general arrangement design, accommodation arrangement design, bridge and engine room design, machinery selection, layout preparation, outfitting design, and fabrication drawing preparation etc. Obviously, most of these topics are typical marine-related problems, but not all are related to context of use or user requirements. The design process did not at any stage involve end-users or end-user representatives for consultation or in receiving feedback in order to improve design. My fellow naval architects and I were unaware of HCD and the important role it can play in ship design because it is not a subject traditionally taught in the marine design curriculum. Rather, we wanted to stick to rules, regulations, and deadlines given by owners or yards by focusing on the technical aspects of the design.

Moving back from the anecdotal to the empirical, the most significant challenge for integrating HF content into maritime education is that discussions about humans is unfamiliar to a discipline primarily grounded in mathematics and engineering. Nevertheless, some degree courses including mechanical, electrical, software design and industrial engineering have already taken steps to additionally integrate HCD knowledge into students' group design activities, and have shown that it contributes towards training students to become socially conscious design engineers (Oehlberg et al., 2015; Pastel et al., 2014; Zoltowski et al., 2010). According to Fila et al. (2014), group design activities in engineering courses are considered as a most effective pedagogical approach to provide the skeleton upon which an instructor can integrate HCD, empathic design (Giacomin, 2014), social science, and humanities disciplines into the engineering design activities in order to transfer the non-technical methods based knowledge to design engineering artefacts.

Group design activities are considered to be a very important part in many maritime design courses around the world, as it helps ensure that graduates are equipped to enter the workplace as practicing maritime engineers (Lee et al., 2013; Miller, 2003; Miller & Olds, 1994; Thomas et al., 2013). Nevertheless, it is noted that the application of HF and HCD activities within maritime undergraduate design projects is virtually non-existent (Mallam, 2016; Myles, 2016; Petersen et al., 2011). Therefore, the studies of Petersen (2012), Mallam (2016), and Myles (2016) suggested an early intervention during the maritime design education as the essential first step for increasing the inclusion of maritime HF in future ship designs. Kuo et al. (2000), The Nautical Institute (2015), and Petersen (2012) have suggested the introduction of practical methods such as seagoing training to motivate undergraduates to follow non-technical matters and end up with usable designs. Petersen (2012, p. 187) stresses that 'engineers are inherently practical people. Do not lecture. Shut up, and engineer'. However, these authors did not investigate their suggestion practically with maritime design undergraduates. Furthermore, the published literature however lacks studies that have been done to integrate HCD knowledge into maritime education.

This study recognises that, if the maritime students are introduced to maritime HF issues as well as the application of an HCD approach during their design projects, they could put it into practice and eventually it would help ensure that graduates are equipped to enter into the workforce with a wider range of skills in designing ships that are truly 'usable'. In addition, the students should be encouraged to carry their newly acquired HCD knowledge forward into their future design teams so that these concepts can be introduced to the future of maritime design. This study is thus initiated aiming for a sustainable teaching intervention for educate maritime design undergraduates in HF and HCD theoretical concepts and to motivate them to utilise their knowledge in the design process. Achieving this in the maritime design space is necessary for shaping ships for people.

1.2 Research aim

As discussed in the previous section, while there is an overt purpose in terms of the lack of HCD education in the maritime domain, there is also a strong personal element behind the motivations for this study. This study therefore seeks to address a practical issue: the common criticism of maritime design education – often articulated as biased towards the technological field, missing any HCD component.

With this in mind, the overarching aim of this research study is to integrate HCD knowledge into maritime design education through undergraduate design projects. In order to achieve this aim, the following three specific research objectives were developed.

1. Constructing a pedagogical framework for integrating HCD knowledge into maritime undergraduate design projects.

2. Operationalise the pedagogical framework and disseminate HCD knowledge through an action research study.

3. Evaluate the effectiveness of the pedagogical framework and HCD knowledge dissemination activities to reflect its outcomes for further improvements and validation.

The strategic, long-term aim of this research is for filling the future need of human-centred designs in the maritime domain by educating maritime design students and motivating them to incentivise the members of their design teams.

1.3 Dissertation structure

The construction of the next chapters of this dissertation, which can be used as a brief guidance to understand how the research objectives have been addressed, is outlined below.

Chapter 2: Literature review

This chapter presents the concepts and background study appropriate as regards HF/E, HCD, ship design practice, and maritime design education, and identifies research gaps that need filling.

Chapter 3: Pedagogical framework and research context

This chapter explains the pedagogical framework and research context of this study. Firstly, it reviews the existing literature of recent initiatives to develop holistic design engineers through holistic engineering education. It then reviews the literature of particular student-centred pedagogies, and associated theoretical foundations, that were used to construct the teaching framework. It further explains the operationalisation of the teaching framework to impart HCD knowledge into the maritime undergraduate design projects, as well as to create HCD design leaders (i.e. HCD champions of this study) for the future of maritime domain who would carry the newly acquired HCD knowledge forward to influence future design teams.

Chapter 4: Methodology

An overview of the Action Research (AR) method, which is identified as appropriate for studying the success of the pedagogical framework, and HCD knowledge dissemination activities is discussed in this chapter. It then further includes the data collection and analysis methods, ethical framework, and quality indicators of AR.

Chapter 5: Action cycle 1

This chapter presents a detailed description of the first action cycle of this research study. It comprises the initial planning of the HCD knowledge dissemination activities delivered through the pedagogical framework. It then explains the delivery of the scaffolding program and the findings, along with the researcher's reflections. Furthermore, it discusses the successes of the cycle, as well as necessary modifications to the HCD knowledge dissemination activities to be included in action cycle 2 in order to improve on the first action cycle.

Chapter 6: Action cycle 2

The outcomes of the second action cycle are presented in this chapter. Although a similar structure to chapter 5 is followed, within this chapter the differences to chapter 5 are discussed in order to avoid repetition. Findings of this chapter lead to the identification of the effectiveness of the pedagogical framework and modified HCD knowledge dissemination activities to effectively transform technical mind-sets to appreciate and use an HCD approach in the maritime design process.

Chapter 7: Discussion and conclusion

This chapter summarises the main findings, in regards to the research aim, and contains a discussion and conclusions based on the findings from the two consecutive years of AR study. In addition, the quality and validity of this AR study, contributions, and recommendations for future research are also discussed.

Appendix

At the end of this dissertation an appendix is given containing: the approval documents from the Human Research Ethics Committee (Tasmania) for conducting the research; questions included in the questionnaire and interview; and a detailed description of the HCD knowledge dissemination activities delivered within this study. It also contains published academic papers of this study.

1.4 Limitations

The findings of this research study can only be generalisable to the maritime academic institutes that follow technology-focused design programs that lack HF or HCD-related units. The pedagogical framework and the HCD knowledge dissemination activities have been tested and validated in two consecutive years of AR study, with a total of 69 maritime design undergraduates who undertake yearlong design projects under the Problem-Based Learning (PBL) pedagogy. Therefore, to implement the pedagogical framework and HCD knowledge dissemination activities, it is necessary for the undergraduate courses to have a comprehensive PBL-driven design project unit for maritime design. This study utilised AR as the methodological framework, which needs participants to contribute to the study throughout the yearlong action cycle. Since the participants were undergraduate students who volunteered to participate, there was a risk of losing their interest to participate while research progresses. It was therefore necessary to do a careful selection of volunteers, which is discussed in sections 5.4.3 and 6.2.3.

1.5 Contributions

The findings of this research study will contribute greatly to the benefit of academia and the maritime domain. Academic institutions that run PBL-driven maritime design projects have an opportunity to utilise a tested and validated teaching framework and the HCD knowledge dissemination activities to integrate HCD knowledge into their maritime degree course. Furthermore, this thesis has collected a large amount of practical evidence from an insufficiently researched domain. This will help those who wish to follow in the footsteps of this research. In addition, The HCD champion concept introduced in this study is a novel approach to disseminating HF and HCD concepts in the maritime domain.

1.6 The use of 'I'

This research study employs AR as the methodological framework. Thus, to give the reader a firm sense of my action steps, not the action of others, and since I was the person at the centre of the research, the first person pronoun 'I' will be used within this thesis. It is important to note that, the focus on 'I' is not accidental, but a considered, self-reflective aspect of the methodology employed.

1.7 Summary of publications

Academic papers of this study are briefly summarised here. It should be noted that these papers only contain some of the key findings of this study and should not be regarded as the overall outcome, which includes the material in the exegesis.

Article 1

Citation: Abeysiriwardhane, A., Lützhöft, M., & Enshaei, H. (2014). Human Factors for Ship Design; Exploring the Bottom Rung. *Transactions of the Royal Institution of Naval Architects Part C1: International Journal of Marine Design, 156*(1), 153-159.

Summary: This article summarises the findings of a classroom questionnaire, and an onboard survey conducted on the Australian Maritime College (AMC) research vessel Bluefin after HF-related activities. Final year maritime design students at AMC were the participants of these studies. A total of 35 responses were received for the classroom questionnaire and 38 for the onboard survey. The aim of the classroom questionnaire was to evaluate the students' current understanding and awareness of maritime HF and HCD concepts. The questionnaire findings show the students' lack of HF and HCD understanding and awareness. They did not recognise the significance of the HCD approach in ship design and suggested using designers' common sense to produce user-friendly designs. Furthermore, a majority of the students believed if the users were well trained, most of the onboard accidents could be eliminated. In addition, none of the students were exposed to maritime HF-related topics during their undergraduate studies. Unlike the classroom questionnaire findings, the findings after the onboard HF activities show how important those were to stimulate the students' awareness of HF issues onboard. The majority of the students understood the significance of including HF in the early stages of the ship design process. However, the overall findings confirm the common criticism of maritime design education, often articulated as biased towards the technological field, thus the students are not aware of HF, HCD and operational issues onboard ships. Therefore, the paper concludes the great need of having HF and HCD taught in a systematic, engineering-oriented fashion by integrating it in the maritime design education.

Article 2

Citation: Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S., & Enshaei, H. (2015). Investigate and Stimulate Future Maritime Designers' Context of Use Knowledge: A Workshop Approach. *Transactions of the Royal Institution of Naval Architects Part C1: International Journal of Marine Design, 157*, 179-193.

Summary: This article presents findings of a workshop conducted with final year maritime design undergraduates (enrolled in the design project unit at AMC) to stimulate their Context of Use (CoU) knowledge within maritime design. Students were asked to build low fidelity (lo-fi) prototypes of selected work scenarios on ships, and to prepare mobile phone videos of that scenario. A team of six experienced seafarers were available for consultation as end-user representatives. Prototypes and videos prepared by each team were subsequently analysed, together with researcher observations, students' feedback sheets, and photos and notes taken during the session. Findings exhibit that the availability of the experts during the session was helpful for most of the students in order to understand and improve their knowledge of CoU. Most of the students consulted end-user representatives while preparing the lo-fi prototypes. Furthermore, it is identified that the students' understanding of situations on ships could be improved, despite the fact that they did contain elements of the context in many work scenarios – more on general layout and crew members present, and less on individual crew roles.

Article 3

Citation: Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S., & Enshaei, H. (2016). Human Centred Design Knowledge into Maritime Engineering Education; Theoretical Framework. *Australasian Journal of Engineering Education*, 21(2), 49-60. DOI:10.1080/22054952.2017.1287038

Summary: This paper presents the pedagogical framework constructed, and its proposed application to facilitate the maritime design undergraduates to learn HF and HCD and apply it during design projects. This framework connects Peer-Led Team Learning (PLTL) pedagogy and a Problem-Based Learning (PBL) based maritime design project unit, in conjunction with associated theoretical foundations of both pedagogies; Vygotsky's Zone of Proximal Development (ZPD) theory and the scaffolding concept. The connections between these pedagogies and theoretical footings, as well as overlaps are discussed in this article in order to construct the teaching framework.

Article 4

Citation: Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S., & Enshaei, H. (2016). Incorporate Good Practice into Ship Design Process; Future Ship Designers Meet End -Users. Paper presented at the *ERGOSHIP 2016: Shaping Shipping for People* Melbourne, Australia, 6-7 April.

Summary: This paper presents findings of a 'designers meet end-users' workshop that was conducted with final year maritime design undergraduates who had enrolled in the design project unit at AMC. A team of seven experienced seafarers were present as end-user representatives to provide HF feedback for improving the designs of students. Students facilitated a walkthrough of their designs for the end-user representatives. Data collection included a debriefing meeting with experts, student feedback, and researcher observations. The end-user representatives highlighted possible design alterations within the general arrangement and other layout drawings to make the designs more user-friendly than their originals, indicating that CoU knowledge of the students could be improved further. Based on student feedback, 92% acknowledged the value of having such workshop to improve their knowledge by meeting end-user representatives, and 88% of them requested it to be repeated. They experienced the importance of involving end-users during the design stage. The findings conclude that such efforts would significantly support stimulating knowledge of maritime designers on workplace processes, tasks, equipment, potential risks, and operational issues on board ships, and to establish a clear understanding of the situations in which the design would be used.

Article 5

Citation: Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S., & Enshaei, H. (2017). Stimulating Human Centred Design Understanding and Awareness in Maritime Design Students: A Demonstration of an Action Research Approach. *Transactions of the Royal Institution of Naval Architects Part C1: International Journal of Marine Design* (Accepted for publication).

Summary: This research article presents the findings of a yearlong first action cycle of this study. Final year maritime design students who had enrolled in the design project unit at AMC (2015 academic year – 41 undergraduates) were facilitated through planned HCD knowledge dissemination activities based on the teaching framework presented in article 2. The overall effect of the program was determined through analysis of the records maintained in the researcher's journal, responses from a questionnaire, interviews, and from the results of a design project report review. The findings establish that the pedagogical framework and the HCD scaffolding program delivered contribute to improving the students HCD understanding. However, improvements were identified and it was decided to further test and validate the whole program, including enhancements, with the next cohort of maritime design undergraduates.

Chapter 2

Literature review

Working and living as a seafarer on board a ship or any other floating structure is a high-risk occupation, with long hours and repetitive living and working settings, in addition to harsh weather conditions. This realisation can lead to questioning whether the design of ships supports seafarers as much as possible, since a ship is not only a place of work, but also a home for them. With this in mind, this chapter presents the background of this study and identifies research gaps that need filling.

2.1 Ergonomics and human factors

The world ergonomics derives from the Greek ergo (work) and nomos (law, or system), can be defined as the applied science of work, and its foundations date back to Ancient Greece or even the Stone Age with the making of tools (Meister, 1991). Ancient Greeks were applying ergonomic practices to household tools, construction sites, and surgical theatres. Initial areas of interest were worker anthropometry, working postures, fatigue, musculoskeletal disorders, work environment and tool design (Franco & Franco, 2001). However, ergonomics as a scientific discipline was first introduced in 1857 by the Polish scientist Wojciech Jastrzebowski (Jastrzebowski, 1857) and later coined by the British chemist and psychologist Kennet Frank Hywel Murrell in his military studies during and post-world war II (Chartered Institute of Ergonomics and Human Factors, 2016).

In Europe during the 1950s, Ergonomics began to be connected with the study of human physical attributes in industrial contexts for the design of workstations and work processes. It was in North America that the terms human factors and human factors engineering originated, they applied the same methods as ergonomics but not necessarily to work settings such as military or technology for personal use (Helander, 1997; Koskinen et al., 2011). The European Productivity Agency (EPA) established a human factors section in 1955, which led to an international association of work scientists in 1957, which, in turn, formalized the International Ergonomic Association (IEA). The initial focus of this association was on the well-being and productivity of the workers from a biological standpoint, but this soon expanded towards a focus on cognition and on non-vocational activities due to the advancement of technology (Helander, 1997). Despite the initial differentiation, human factors and ergonomics are today treated equally and have merged into the same discipline (Wilson, 2000). The IEA provides the following definition:

> 'Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimise human well-being and overall system performance' (IEA, 2016)

According to IEA (2016), the domains of specialisation within human factors that represent human competencies are: physical human factors, cognitive human factors, and organisational human factors. Physical human factors refer to anthropometrical, anatomical, physiological and biomechanical characteristics of the human body related to human activity. This can consist of workplace layout, noise, lighting, motion, vibrations, temperature, working postures, manual handling, and repetitive movements. Cognitive human factors involve competencies such as the design of activities, systems and technology that can fit the human mind and cognitive abilities; mental workload and performance; stress; and decision-making support. Organisational human factors focuses on the optimisation of the organisational context including the organisational structures, policies, cultures and processes for communication and decision-making regarding who hold which skills and knowledge, who has done and will do what, as well as other features of the human capital and intellectual property.

Consequently, human factors as an applied scientific discipline adopts a multidisciplinary and socio-technical systems perspective, considering the various elements of a work system and their interactions. This involves the study of human capabilities, limitations and needs, taking into consideration the physical, cognitive, social, organisational, contextual and environmental aspects of work, in order to fit the task and tools to the human (Hollnagel, 2014; Wilson, 2000). Taking such a holistic approach can capture not only the attributes of the different elements but also of their relationships and emergent properties (Vicente, 2006). The research within this thesis when referring to the scientific discipline itself, 'Human Factors (HF)' is chosen over the other alternatives in order to establish consistent terminology.

2.1.1 Participatory approach of the HF discipline

Besides the holistic perspective, user participation is an essential characteristic of the HF discipline (Langford et al., 2003). Research on the concept of user participation dates back to the 1970s, when in Scandinavia the Collective Resource Approach was founded to intensify the value of industrial production by involving workers in the design and development of new work systems (Gill, 1996; Kraft & Bansler, 1994), and in the democratisation of computer automation (Steen, 2011). Other European programmes like the German humanisation of work (Kissler & Sattel, 1982) and the British Lucas Plan of socially useful production and technology (Smith, 2014) were also important players in the shift to participatory approaches (Gill, 1996). In the early 1980s, discussion around the concept of user participation raise in the HF community (Langford et al., 2003).

Participatory approaches to design establish a collaborative framework within an HF intervention process that organises relevant users and stakeholder groups affected by the change. The idea is that discussions amongst stakeholders who do not necessarily have skills or expertise in design or HF can stimulate the identification and codification of pertinent tacit knowledge related to the process. These could include, but are not limited to, identifying aspects of their workplace, systems or tools that can be improved, developing solutions for problems according to their knowledge and experience, and supporting the development of such solutions (Glina et al., 2011). Involving users in design thus can enhance the meaningfulness of work; optimise performance; attenuate work-related health issues; increase learning within the organisation, comfort and productivity; improve design ideas and solutions, and facilitate implementation (Glina et al., 2011; Haines et al., 2002; Österman et al., 2011).

User involvement can take different forms in terms of direct or indirect (via representatives) participation (Haines et al., 2002; Langford et al., 2003). Users can also be involved in a passive fashion by being given directed tasks or asked to comment on design concepts developed by others. Active user involvement can increase the acceptance and commitment of the users to the new product as they understand that the design is being suited to them rather than enforced, and produce a sense of control and ownership, on the assumption that the users later experience the things they helped develop or improve upon (Glina et al., 2011; Maguire, 2001). HF and user participation can be integrated into the design process through participatory design (Langford et al., 2003), participatory ergonomics (Haines et al., 2002), human centred design or user centred design (ISO, 2010), or co-design (Sanders & Stappers, 2008). Even though they might differ in their origins and nature, they hold principles in common and engage people in the design process (Steen, 2011).

2.2 Human centred design approach

Design in the 1950s and early 60s was mainly governed by a rationalistic view, followed by operations research and systems theory, and the design methods movement. This movement was however criticised as insufficient in accounting for the human, social, and artistic facets of design. The integration of ethnography, as well as behavioural and social psychology into the design process began to play an increasingly important role in design practice and in mitigating the preceding mechanistic paradigm. This turned design into an emergent scientific field of study, and what was an apprenticeship, into academic skill development (Koskinen et al., 2011). For this reason, the tacit knowledge of design practitioners had to be captured and articulated through design research (Koskinen et al., 2011). This design shift served as a catapult into the User Centred Design (UCD) movement.

UCD developed from a combination of usability engineering, human-computer interaction as well as participatory approaches in the 1970s (Williams, 2009). UCD firstly became prevalent in computer science and artificial intelligence (Giacomin, 2014), but in the 1990s it also became widespread within industrial and interaction design, and was popularised by the famous Silicon Valley design company IDEO (Koskinen et al., 2011). More recently, the term Human Centred Design (HCD) rather than UCD has been made official by the International Organisation for Standardisation (ISO). In practice, however the terms of UCD and HCD are often used synonymously.

As per ISO 9241-210:2010, HCD is an 'approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques'. Making a product 'more usable' is about improving usability (ISO, 2010). There are five design stages and six key principles that should be considered if the benefits described above are to be attained. The stages of HCD are shown in Figure 1:

- Plan the human centred design process
- Understand and specify the context of use
- Specify user requirements
- Produce design solutions to meet user requirements
- Evaluate designs against requirements
- Iteration if needed, or finalisation

These are carried out in an iterative fashion, with the cycle ideally being repeated until the particular usability objectives have been attained.

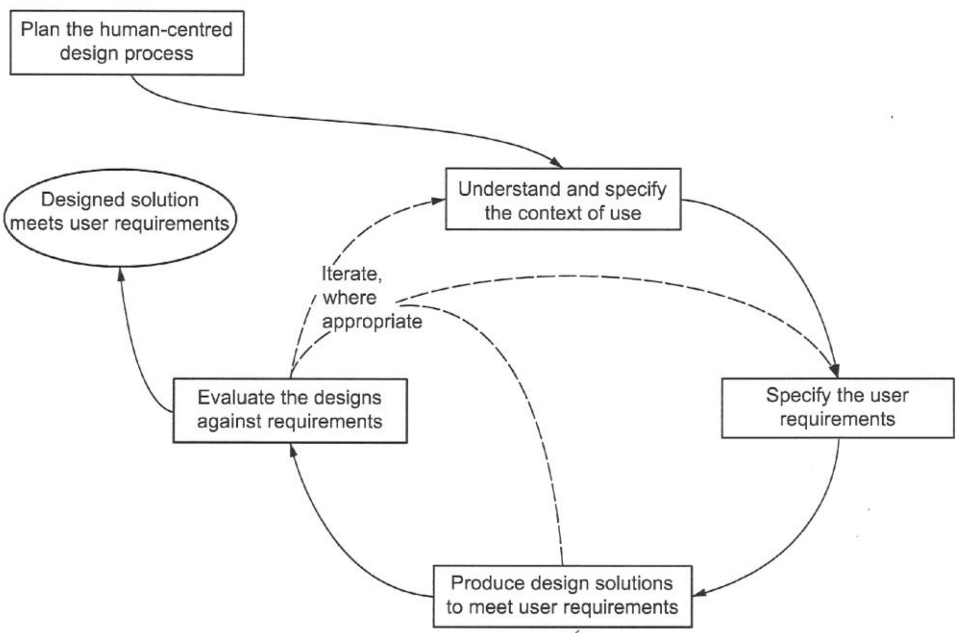


Figure 2.1: The interdependence of HCD activities – ISO 9241-210 standard (ISO, 2010).

Based on ISO 9241-210:2010, if the application of a HCD approach is to be successful, it must be carefully planned and managed throughout all parts of the development process. The planning of the HCD process shall integrate HF into the project by evaluating how usability relates to the purpose and use of the design. The designer should be able to collect high-level information about the following in order to be successful in planning stage: Why is the system being developed? What are the overall objectives? Who are the intended users and what are their tasks? What are the technical and environmental constraints? What key functionality is needed to support the user needs? What is the overall workflow (Maguire, 2001).

The next step of the HCD approach strives to establish a clear understanding of the situation in which the design will be used, including goals which users are expected to achieve, tasks and equipment, and the physical, social and organisational environments. Collectively, these considerations are identified as understanding and specifying the context of use. When a design is developed, it is intended for a user population with certain characteristics, to be used for a specified purpose within a certain context. The intended user group will have certain goals, and tasks to perform within a certain range of technical, physical and social or organisational conditions, any of which may affect its use. Therefore, the usability of the design mainly depends on this kind of understanding of the context of use. The purpose of the next step, which is to 'specify user requirements' is to establish, clarify and communicate the requirements of the users of the design. It includes requirements derived from user needs and the context of use and requirements arising from relevant ergonomics standards and guidelines (ISO, 2010; Maguire, 2001). The next steps of this approach are to incorporate user requirement data into the design solution, and then to evaluate those design solutions against user requirements. During the evaluation step, it is required to test the design, applying such methods as walking through it with the real users and obtaining feedback from them, using HF evaluation software, evaluating it against ergonomic and HF criteria and guidelines, and using a HF tracking database which can identify HF issues in the design drawings (ISO, 2010; Maguire, 2001).

This approach has been perceived as a research-driven approach rather than being design-driven (Koskinen et al., 2011). According to Giacomin (2014), one of the issues with designing for the user is the focus on the cognitive functions and predetermined usage patterns of the product, and distancing the product from possible future alternative usages that are difficult to predict, as they emerge during usage within social interactions and settings. This is one of the reasons that made Norman (2005) shift his support of HCD towards Activity Centred Design (ACD) instead, as he believed that by focusing on the activities in which the product can be used one can open up for a variety of future usage possibilities which the sole focus on the user does not enable. Others have suggested that this is but a misconception of HCD/UCD, which encompasses the principles of ACD (Williams, 2009). Today, HCD has become an overarching approach or a basis for usability, empathic design, design for customer experience, emotional design (Giacomin, 2014; McCartan, Harris, et al., 2014), design thinking (Brown, 2008), user centred systems design or human centred systems design (Gulliksen et al., 2003), activity centred design and goal directed design (Williams, 2009), as well as systemic design (Lurås, 2016).

Applying HF through HCD approach has a range of benefits including, but not limited to, reduced work-related musculoskeletal disorders, injury rates and subsequent personal and economic injury costs; reduced employee turnover, absenteeism, errors, training and support, thus enhancing effectiveness, efficiency and satisfaction, other social and economic benefits for the users (Fritzsche et al., 2014; Hendrick, 2003; Maguire, 2001). For example, human well-being, accessibility and sustainability can be improved, reducing discomfort, stress and a propensity for errors, it can enhance the commitment and trust of the users towards the system as well as the commercial and competitive advantage, and it can improve the image and reputation of the organisation (Maguire, 2001).

2.3 The maritime domain: HF issues and design considerations

Maritime transportation is the lifeblood of the global economy, having responsibility for approximately 90% of world trade (ICS, 2014). According to the history of world trade, shipping has been a driving force since early sea trade in Mesopotamia five-thousand years ago, and has gradually evolved towards the tightly knit global industry of today (Österman, 2012; Stopford, 2009). Worldwide, there are more than 90,000 vessels, registered in over 150 nations and more than one and a half million seafarers transporting goods for the benefit for the world's population of about 7.4 billion (Review of Maritime Transport, 2016).

Regardless of increased technology, regulations, capacity and other initiatives for increased safety, there are still a significant number of accidents that occur at sea. It has been estimated that 60-80% of all casualties at sea are caused, at least in part, by operator/human error. In 1993, the United States Coast Guard reported that 80% of maritime accidents were caused by human error (United States Coast Guard, 1995). In 1994, a United Kingdom Protection and Indemnity (P&I) Club study on major P&I claims between 1987 and 1993 indicated that 63% of these incidents were caused by human error (United Kingdom P&I Club, 1994). Furthermore, their studies show that human error costs the maritime industry US$541 million every year. In addition, a review of the accidents from United States Coast Guard databases over the reporting period of 1999 to 2006 show that, human error continues to be a dominant factor in 80 to 85% of accidents. Of these about 50% of were initiated by human error, and another 30% of associated with human error (McCafferty et al., 2006).

For decades, the maritime industry has held a belief that technology, regulations, and more training will address these maritime safety concerns (Grech et al., 2008). However, the analysis done by Allianz Global Corporate and Specialty (2016) and the International Union of Marine Insurance (2016), along with the aid of Lloyd's List Casualty Statistics for the period of 2001-2016 revealed that the insurance claims over US$10 million have shown a growth even though total ship losses are declining. Furthermore, occupational injury rates onboard are still above those of most land-based industries (Hansen et al., 2002; Oldenburg et al., 2010). Besides, still human error is apparently to blame in most maritime accidents (Allianz Global Corporate and Specialty, 2016).

Seafaring is a unique occupation that has very different working (and living) conditions compared to typical land-based professions. The transient nature of shipping physically and psychologically isolates the crew. Work, rest and leisure activities occupy the same confines and individuals are away from their home, family, friends and 'normal' onshore life and routines for long periods (Louie & Doolen, 2007). Furthermore, working hours often irregular and around the clock, disrupting circadian rhythms, creating fatigue and stress in crew which is detrimental to operations, overall ship safety and has harmful effects on personal health (Bloor et al., 2000; Harrington, 2001). In addition, humans working within moving environments are also susceptible to degraded physical (both gross and fine motor tasks) and cognitive skills, increased potential for whole-body fatigue, and motion sickness (Calhoun, 1999; Dobie, 2000, 2003; Jensen et al., 2005). In heavy weather (e.g. high winds, waves, rain, low visibility, etc.) the simple act of standing or walking can be challenging and severely degraded or inhibited by the environmental conditions, let alone the demands of successfully operating or maintaining a ship safely at sea.

It is obvious that ship crew make mistakes peculiarly in such working conditions. Nevertheless, it is prudent to investigate the cause for errors by considering them as symptoms, or starting points of investigations (Dekker, 2002; Hollnagel, 1983; Hollnagel & Amalberti, 2001), rather than concluding that the errors occurred solely due to the seafarers. The causes of human errors are complex, however, when analysing the underlying causes for the maritime accidents, many of them are linked with HF issues which in turn can be traced back to the shortcomings of designs (Dobie, 2003; Earthy et al., 2006, 2010; Joiner, 2007; Lützhöft, 2004; Lützhöft, Petersen, et al., 2017; Rasmussen, 2005; Ross, 2009; Rothblum, 2000; Sherwood Jones, 2005b; Squire, 2007, 2014; The Nautical Institute, 2015; Walker, 2011).

Widdel and Motz (2000) evaluated ship bridges from an HF perspective by carrying out task analyses, questionnaires and interviews with watchkeeping officers. The authors also collected information on what mariners require to achieve safe and efficient operation within those bridges. One of the key findings of their work was that inappropriate bridge layout and interface design, without consideration of HF, was foremost reason behind issues on board. As a result of the investigation, 652 HF requirements were listed regarding the design of the layout and the information system of a ship bridge to consider for future ship bridge designs.

A survey on seafarer habitability and its implications was carried out for Royal Navy ships by Strong (2000), and provides valuable indications of personal priorities and preferences for habitability features in naval ship designs. This analysis highlighted the requirements of adequate levels of privacy, which are necessary for individual and social relaxation. One of the major conclusions from this study was to consider HF needs from a social, psychological and architectural design perspective that could further inform the design of ship accommodation. A similar study conducted by Hardwick (2000) also suggested improvements such as increased sleeping space and personal storage, improving ambient conditions, and providing adequate space for relaxing. They highlighted that these improvements will significantly reduce seafarer fatigue which is counted as a potential cause of or contributor to human error.

Lützhöft (2004) conducted a four-year study, where 15 passenger and cargo ships were visited and observed, and 40 bridge officers were interviewed. It was found that many technically-integrated maritime systems were neither well integrated from a human cooperative point of view, nor from a technical point of view. It further pointed out that seafarers learn to cope with problems by outsmarting the system, performing integration work, and sometimes by compromise. The research study stressed the significant omission of user’s voice in the design process of ship bridges, and it highlighted the need for inclusion of HF to improve ship bridge designs.

Ellis (2009) discussed the well-being of seafarers from a vessel design perspective, including levels of noise, light, the view from windows, aesthetics, confinement and other indirect factors such as social support, social networks and restoration. The research indicated the negative effects of many of these factors on ship staff, which can lead to increased fatigue. Several inexpensive solutions for increasing the well-being of seafarers were proposed, such as fitting daylight bulbs rather than neon strip lights and decorating accommodation facilities with aesthetically pleasing colours. According to the author, the design of accommodation and recreational facilities should be seen not just as an issue relating to seafarer health, but also one that may indirectly affect work performance and effectiveness.

Lundh (2010) conducted a research study on board merchant vessels in Sweden to explore the interaction between crew, and their adaption to the work situation in the engine control room. The results showed many deficiencies in engine rooms which did not comply with ergonomic principles or even work health and safety requirements. She concluded that prevailing knowledge in HF is not being fully utilised in the design of the engine department of ships, and stressed the need and significance of taking into account HF requirements during the process of ship design. Besides, within the engine department, the crew are exposed to additional risks for injury and disease which are associated with the enclosed engine room space and its challenging work conditions (Lundh, 2010; Nielsen & Panayides, 2005; Orosa & Oliveira, 2010). Engine crew are exposed to risk factors such as high noise levels that can result in permanent hearing loss (Svendsen, 1999) and hazardous chemical compounds found in oils, soot and engine exhaust that can contribute to developing certain cancers (Forsell et al., 2007; Nilsson et al., 2004). The harsh ambient conditions can contribute to heat stress and thermal shock (Orosa et al., 2010), while tasks that involve heavy physical labour can potentially put engine crew in poor postural positions, increasing the risk for physical injury (Lundh et al., 2011; Seif & Muftic, 2005).

A series of studies have been conducted by Rumawas (2016) to investigate HF in ship design and operation. The case studies he conducted on offshore supply vessels operating in the Norwegian Sea revealed that HF considerations should be inserted as one of the criteria in the ship design spiral. This research study highlighted that user opinions which cover all departments on a ship should be taken into consideration within the design process. Ahola (2017) conducted his research study about how passengers perceive safety on board a cruise ship during normal operating conditions. User data were collected through 19 interviews and 38 days of observation in an authentic cruise ship environment during five cruises. The research highlights the importance of HF consideration on designing safe and comfortable ships, so as to minimise passenger stress and increase satisfaction. The previous studies on HF issues and related design considerations as discussed above are summarised in Table 2.1.

Table 2.1 Summary of the literature review on HF issues onboard linked with design considerations.

Author	Study	Key findings
Widdel et al. (2000)	Evaluate ship bridges from an HF perspective.	Inappropriate bridge layout and interface design, without consideration of HF, was foremost reason behind issues on board.
Strong (2000)	A survey on seafarer habitability and its implications for Royal Navy ships.	HF needs should be considered in design of ship accommodation from a social, psychological and architectural design perspective.
Hardwick (2000)	A survey on seafarer habitability and its influence on seafarer fatigue.	Improvements in HF will significantly reduce seafarer fatigue.
Lützhöft (2004)	Field study onboard ship bridges of 15 passenger and cargo ships.	Technically-integrated maritime systems were neither well integrated from a human cooperative point of view, nor from a technical point of view.

Author	Study	Key findings
Ellis (2009)	Well-being of seafarers from a vessel design perspective.	Design of accommodation and recreational facilities directly affect work performance and effectiveness.
Lundh (2010)	Interaction between crew and their adaption to the work situation in the engine control room.	HF is not being fully utilised in the design of the engine department of ships.
Rumawas (2016)	HF in ship design and operation of offshore supply vessels operating in the Norwegian Sea.	HF considerations should be inserted as one of the criteria in the ship design spiral.
Ahola (2017)	Cruise ship design and how passengers perceive safety on board.	HF considerations should be inserted as one of the criteria in the ship design spiral.
Rothblum (2000), Dobie (2000), Khandpur (2000), Dobie (2003), Rasmussen (2005), Sherwood Jones (2005b), Earthy et al. (2006), Joiner (2007), Squire (2007), Ross (2009), Earthy et al. (2010), Walker (2011), Lützhöft et al. (2011), Squire (2014), The Nautical Institute (2015), Lützhöft, Petersen, et al. (2017)	HF issues onboard and how those linked with design considerations.	Many of the underlying causes for the maritime accidents are linked with HF issues which in turn can be traced back to the shortcomings of designs.

Moving from subjective to statistical studies, Rowley et al. (2006) found that nearly one-third of maritime accidents have been linked to shortcomings of design, based on the United States National Transport Safety figures. In a recent study by Kataria et al. (2015), inadequacies within the design were the dominant factor for two-thirds of the 129 publicly available maritime casualties. Furthermore, Sherwood Jones (2016) from an HF perspective, analysed data of 66 deaths in British shipping 2003-2012, collected by Roberts et al. (2014) and found that in 64% (42 people) of the cases, the fatalities could have been avoided by considering HF in the early design stage. The main contributors are well known in shipping; slips, trips, falls in mooring and enclosed spaces (Sherwood Jones, 2016).

Eventually, design shortcomings affect the mental workload of seafarers, some can affect the crew's ability to sleep, and others affect the level of physical stress, which can then lead to poorer operations, higher training costs, and an increased risk of failing at the task as well as increased human errors and fatalities (Holden et al., 2013; Sherwood Jones, 2016). According to Miller (1999, p. 7), 'cannot overcome human errors induced by poor design of the workplace with more training, more manuals or written procedures, exhortations to work more safely, or threats of punitive actions for job accidents'. Therefore, the early stages of a ship design present under-utilised opportunities to consider HF in order to 'design the problem out' instead of adapting the users to the design (Rothblum, 2000). This can reduce design-induced errors, work-around and retrofit cost. In fact, the growing awareness within the maritime industry is that HF needs to be considered in ship design through a HCD approach to reduce the potential for operator error, if seafarers are truly to operate ships and systems safely and efficiently.

The HCD cycle complements any design approach employed by the designer. For example, the general design model use by maritime designers for ship design based on Evans (1959) or Eyres (2001) can be complemented with HCD (Vries et al., 2015). Costa (2016) carried out a study which explored and disseminated some of the success factors of HCD which seafarers believed could benefit them as ship users. This was done by cross-examining data from two focus group interviews comprised predominantly by participants with seagoing experience. The findings highlighted HCD and its participatory principle as a means of attaining a set of benefits at physical, cognitive, psychosocial, organisational, and socio-political levels, and ultimately attaining safer maritime operations. Likewise, numerous studies in maritime domain discusses the systemic benefits of using HCD approach during the ship design and build process to improve the overall safety and quality of work and life onboard (Dobie, 2003; Earthy et al., 2006, 2010; LR, 2008b; Lundh, 2010; Lurås, 2016; Lützhöft, 2004; Lützhöft et al., 2007; Petersen, 2012; Pomeroy et al., 2002; Rasmussen, 2005; Sherwood Jones, 2005b; The Nautical Institute, 2015). Furthermore, it is critical to demonstrate the benefits of HCD in quantifiable cost-savings and tangible performance outcomes as good ergonomics is not only appropriately applied knowledge, but should also be cost-effective and practical (Hendrick, 2003). In recent years cost-to-benefit analysis research has strived to fill this gap by investigating the application of ergonomics across a range of domains. Beevis (2003) and Goggins et al. (2008) found that academic research is generally biased towards demonstrating the economic benefits of ergonomics. It is difficult to accurately assign costs and benefits associated to ergonomics applications, while specifically within the shipping industry there is little data on the economics of ergonomics (Österman, 2012; Österman et al., 2010).

However, there are only few design examples available in the public literature to show that maritime designers follow an HCD approach during design process. The first example of ship designs that have incorporated HCD is the Tamar lifeboat owned by the Royal National Lifeboat Institution (RNLI). The aim of its design team was to achieve a ‘fit between people and their work’ (Chaplin & Nurser, 2007). Unlike the traditional ship design process, the Tamar design team facilitated concurrent design processes on a number of fronts, allowing HF issues to be addressed as part of the development of the craft, in areas such as seating design, comfort, workstation layout, lifesaving features, and command and control systems. The design team undertook fundamental research into vessel motions, human capability and shock mitigating seating, which resulted in the development of a new crew seat (Cripps et al., 2003). Furthermore, since the new crew seat would aim to improve safety of crews, it was deemed appropriate to try to keep crews in those seats for as much time at sea as possible. Therefore an integrated electronics system was developed which brings information, operation and control of the boat and its systems to the crew in their seats (Nurser & Chaplin, 2004). This design received positive feedback from users in almost every area of HF consideration (Chaplin et al., 2007).

The second example is the ‘Walk to Work (W2W)’ wind farm support ship designed by DAMEN shipyard, the Netherlands. It took an industrial design approach to getting highly specialised onshore personnel to work offshore based on an identified shortage of qualified offshore personnel. Multiple forms of qualitative research such as interviews with users, creative sessions and story-boarding were conducted to generate user input on working and living on board an offshore wind support vessel. These insights were used to design the vessel which creates an offshore work and leisure solution

(Monchy & Smit, 2015). They concluded that: ‘Designing from a user perspective lead to results which would be different from conventional solutions by naval architects. The human touch was proven to be very important in the case of designing an offshore work and accommodation vessel (Monchy et al., 2015, p. 18)’.

The car and truck career, Harvest Leader, which was designed by Antares Shipping, is another real-world example of the practical implementation of HF dimensions. During the design process of this vessel, feedback from the ship’s crew was gathered and subsequently analysed by the design team, alongside the owners, managers and the shipyard, as a basis of the design solutions (Bialystocki & Costa, 2016). This practice resulted in various design improvements on the ergonomic aspects of the vessel. In addition, this design was used to verify the perceived benefits of applying HCD found in the study of Costa and Lützhöft (2014). Finally, this design represented a success case study that can be utilised by other ship designers. This design team believed that demonstrating real-world HF implications in the design of a vessel is essential for promoting the importance of HCD, and in revealing the possibilities that having HCD as a mental state of ship designers (Bialystocki et al., 2016; Lützhöft & Vu, 2017).

Petersen (2010) undertook an HCD project in a fully industrial context in accordance with ISO 9241-210 (2009). His study dealt with a user-centred common software platform for a ship bridge which spanned navigation and automation systems and applications, including radar, electronic chart display and information system, conning, alarm systems, remote control and automation systems. The development of this product utilised a multi-disciplinary design team to implement an HCD process, including external HF representatives. To incorporate usability goals into the development of a system, Petersen and his research team invited input from all stakeholders during this project. The active involvement of users was considered as paramount during this development process, with an understanding of them and their task requirements, appropriate allocations of function between users and technology, and testing and iteration of design solutions.

Furthermore, a few researchers in the maritime design field have endeavoured to present several concept design proposals, while keeping in mind HF concerns, aesthetics, as well as functionality. While designing these concept proposals, they have studied user tasks, purposes, connection between product and the user and the operational environment. They also have used an ‘emotional design concept’ considering user characteristics, expectations, desires and needs, translating them into a sensitive and balanced design solution. Several examples of these concept proposals are mother-ship concepts for wind farm support vessels (McCartan, Verheijden, et al., 2014), superyacht designs (McCartan, McDonagh, et al., 2011; McCartan, Moody, et al., 2011a; McCartan et al., 2015), a high speed coastal cruiser design for the Chinese market (McCartan, Roy, et al., 2011), a cruise ship design (McCartan, Crotty, et al., 2014), and a sailing yacht design (McCartan, Moody, et al., 2011b). However, these concept proposals have not yet developed further to test and iterate them to be some of the real-world examples of usable designs.

2.4 Maritime design practice

The design process generally consists of developing requirements, conducting analyses, preparing drawings, building electronic models and writing specifications (Eyres, 2001). Ship design is a long and iterative process, divided into stages or phases; concept design, preliminary design, contract design and functional design. Each design stage covers specific issues and considerations. Usually the process starts with the mission statement, like what kind of vessel to be built to carry how much quantity of which particular cargoes in which area of the world. The further the process the more detail the issues cover (Evans, 1959).

Maritime designers have been considering their designs mainly from technical and economical points of view. Their primary undertaking has been responsibility for the main characteristics of a ship, i.e. the size, speed, stability, manoeuvrability, cargo carrying properties, exterior and interior design, to mention some of the primary aspects of naval architecture. In terms of process, they usually follow the traditional spiral concept of ship design (Evans, 1959; Eyres, 2001) to be successful in their designs. Maritime designers use this iterative spiral concept of design to design the exterior of the ship, to provide the basic arrangement of the compartments inside the ship, and determine the size and shape of the hull. They often indicate the detailed interior arrangement of such rooms; initial layouts are however often refined during the subsequent design processes. Furthermore, they make preliminary estimates of speed and the resistance of the hull, intact stability, damage stability, seakeeping characteristics, manoeuvring properties, the weight of the ship, the cargo, as well as of consumables like fuel and water on board during a voyage. Maritime designers balance these properties against trading requirements and building costs for any particular ship. The process always follows certain criteria, rules and regulations, codes, standards.

Once the preliminary design of a new ship is in place, more detailed design activities can start, usually utilising iterative design processes of subsystems or sub-assemblies, which in terms of methodology are comparable to the ship design spiral, but which involve many more specialist disciplines than naval architecture. Traditionally, a ship design – and a ship design office – is divided into the main divisions of hull, machinery and outfit. Structural engineers deal with the design of the hull, marine engineers usually deal with machinery, often aided by electrical engineers for the design of electrical power generation and distribution systems, while the rest of the ship is usually dealt with by a mixture of engineering disciplines involving hydraulics, pneumatics, electronics, ventilation and heating etc. (Eyres, 2001). Throughout this complex process, maritime designers use their own experiences as well as innovative thoughts as, they design or modify a ship, just like designers from any field do. Obviously, most of the topics covered above are typical marine-related problems, therefore, the maritime design practice tends to focus on the technical aspects of design more than on end-users. Thus, the lack of HCD integration into the design process appears to be common in mainstream maritime design (Kuo et al., 2000; Petersen, 2012).

2.5 HCD support for maritime designers

Some of the stakeholders who are responsible for integrating HCD into the ship design process are ship designers, regulators, ship managers, administrators, shipbuilders, ship operators, technical managers, ship surveyors and ship inspectors (LR, 2014; Rasmussen, 2005). While each of these stakeholders may contribute to HCD integration, the degree of influence that maritime designers have on the design process is greater than any other stakeholder, since design work has mainly been executed by them. Therefore, it is expected that raising the designers' HCD awareness and knowledge would be influential. Therefore, some maritime HF specialists together with HF organisations have already taken steps to support and raise designers' awareness and understanding of HF and HCD.

Lloyd's Register (LR) Educational Trust supported the Nautical Institute's (NI) Alert! bulletin (NI, 2003) which was developed to raise the HCD awareness of designers as well as other stakeholders.

Alert! bulletin issues have, among many other subjects, published definitions and explained the scope of HF and HCD throughout a ship's lifecycle (NI, 2006), current issues facing the industry (NI, 2009), and competences required for addressing HF by various stakeholders (NI, 2015b). Many HF specialists and researchers, experienced naval architects, as well as experienced seafarers have contributed their expertise towards developing the HF database. As a result, the online database comprises a variety of research articles (Earthy et al., 2006, 2010; Lützhöft & Petersen, 2009; Lützhöft et al., 2010; Pomeroy et al., 2002; Sherwood Jones, 2005b; Sherwood Jones et al., 2006), presentations (Sherwood Jones, 2005a), instructional videos (NI, 2015c), and educational posters as a maritime HCD and HF study guide.

Along comparable lines, the European Union funded research project CyClaDes (Crew-centred Design and Operation of ships and ship systems) was initiated to promote an increased impact from HF in shipping, across design and operational lifecycles (CyClaDes, 2014). The project brought together a multi-disciplinary team including ship yards, suppliers, and seafarer communities along with industrial and academic experts on ergonomics and work space design, classification societies and flag state administration. This project discussed the barriers to HF integration that occur, and how to best locate, produce, disseminate, and apply HCD knowledge within the overall context of shipping. As a result, one of the e-learning packages this project launched was, 'Training for Designers' to increase HF and HCD awareness, as well as to spread HCD knowledge among professional ship designers. It illustrates how to use and integrate HF knowledge for the benefit of the crew and all stakeholders. Furthermore, it includes introductions to bad design practices, an introduction to HF, bad design that had led to slips, trips and falls, usability and HCD, as well as task analysis and more topics related to maritime HCD.

The European Boat Design Innovation Group (EBDIG) project provide on-line training materials for designers working within the European Boat Design industry to promote 'design for user experience not just marine structures' (EBDIG, 2014; McCartan, Harris, et al., 2014). As a result, they published the e-learning packages called the 'Marine Design Course' and 'Maritime Human Factors' to raise designers' appreciation of the emotional attachment of users to leisure boat designs (McCartan, 2009; McCartan, Harris, et al., 2014). Dobbins et al. (2008) carried out notable research work on HF in High Speed Craft (HSC) by producing an HF engineering design guide. This is a guide to enhance the specification, design, evaluation and operation of HSC. It also has provided guidance on many topics including assisting the designer with the inclusion of features that can reduce exposure to high levels of shock and vibration which therefore help to reduce the risk of fatigue, acute and chronic injuries. Mallam (2016) conducted a study to investigate and identify strategies that facilitate the implementation of HCD solutions during new ship development. It focused on transforming ergonomic knowledge into tangible design support and solutions in naval architecture. Results from this research study have been used to develop a software prototype which employs digital general arrangement drawings as a participatory HCD platform.

As a support for ship designers to apply HCD approach during design, LR has developed a guidance document named 'The human-centred approach – A best practice guide for ship designers' (LR, 2014). This document provides a reference of best practice to support an examination of the extent to which HF issues are considered through the organisation, from corporate strategy to technical design activities. The focus on assessment within this document allows ship designers to take a continuous improvement approach to revising the orientation and scope of their activities with respect to HF.

LR have published two more documents related to the maritime HF and HCD approach. 'Human-centred development – Putting the principles into practice' document intended to assist in the consideration of HF issues when acquiring or developing anything from procedures and training to equipment and software, whether new or revised. It describes the four activities through which information about people is collected and used in design, and how the product is evaluated (LR, 2008a). LR has developed 'The Human Element - An Introduction' document to give overview of the issues that HF brings. It introduces many of the issues of which shipowners, ship managers, designers, and other stakeholders in marine safety need to be aware. Perhaps most importantly, it also introduces the types of activities that can be carried out to address HF issues onboard ships. As a summary, the efforts taken by maritime HF specialists and HF organisations to raise designers' awareness and understanding of HF and HCD is given in Table 2.2.

Table 2.2: Summary of the efforts taken by maritime HF specialists to raise designers' awareness and understanding of HF and HCD.

Author/Organisation/Project	Summary
Nautical Institute (NI) and HF specialists: NI (2003), NI (2006), NI (2009), NI (2015b), Earthy et al. (2006), Earthy et al. (2010), Lützhöft et al. (2009), Lützhöft et al. (2010), Pomeroy et al. (2002), Sherwood Jones (2005b), Sherwood Jones et al. (2006),	Developed a HF database. Published definitions and explained the scope of HF and HCD throughout a ship's lifecycle, current issues facing the industry, competences required for addressing HF by various stakeholders.
The European Union funded research project CyClaDes (CyClaDes, 2014)	Launched e-learning package - 'Training for Designers'.
The European Boat Design Innovation Group (EBDIG) project (EBDIG, 2014)	Published e-learning packages - 'Marine Design Course' and 'Maritime Human Factors'.
Dobbins et al. (2008)	Produced HF engineering design guide for High Speed Craft (HSC).
Lloyd's Register (LR) HF group (LR, 2014)	Developed a guidance document named 'The human-centred approach – A best practice guide for ship designers'.
Mallam (2016)	Developed a software prototype which employs digital general arrangement drawings as a participatory HCD platform.

In addition, The International Maritime Organisation (IMO) and other classification societies such as American Bureau of Shipping (ABS) have taken some action on more specific concepts involving ergonomics and user-centred applications, acknowledging their importance in contributing to enhanced safety and efficiency in shipping and ship design (e.g. (IMO, 1997, 1998, 2004, 2006), (ABS, 2003, 2013, 2014)). However, the IMO's mandatory rules and regulations for the construction and operation of marine structures (e.g. The International Convention for the Safety of Life at Sea (SOLAS Convention) (IMO, 2009) or The International Convention on Standards of Training Certification & Watchkeeping (STCW Convention) (IMO, 2011)) do not include detailed ergonomics support, which is presently only available in the form of non-mandatory guidelines (Mallam & Lundh, 2013).

2.6 Maritime design education

Even though the maritime HF researchers and organisations have already taken effort to raise the ship designers' HCD awareness, still the maritime design undergraduate education tends to focus on technical aspects of design more than on the end-user requirements, which has made it difficult conveying an significance of HCD and usability mind-set (Kuo et al., 2000; Myles, 2016; Petersen, 2012; Walker, 2011). Besides, the majority of design undergraduates are very likely have little or no direct experience with seagoing ships, marine engineering practice, or even first-hand knowledge about the operation of ships (Lützhöft, Petersen, et al., 2017). As discussed by Petersen et al. (2011), sometimes it is difficult to attract a technical mind-set to use non-technical approaches. This can be identified as the natural inclination of design engineering and Gardner's description of engineers' descriptive intelligences is a useful tool in describing the archetypical design engineer from this perspective (Gardner, 2006a).

According to Gardner (2006a), perhaps not everyone is cut out to become a socially conscious design engineer. Perhaps some are to be archetypical design engineers. He states, 'anyone involved with tangible products of any sort is necessarily using naturalist intelligence' Gardner (2006a, p. 38). He elaborates that the archetypical design engineer is gifted with naturalist intelligence as well as spatial intelligence, bodily-kinaesthetic intelligence, and logical-mathematical intelligence (Gardner, 2006b). Naturalistic intelligence, which builds on pattern recognition, gives design engineering the capability to discriminate between seemingly similar constructs, spanning functions and brands, while spatial intelligence provides the capability to form and operate on mental images. These maps directly into one of the preferred ways of communication in design engineering: drawings, sketches, and models which are production interlinked with 'technological' intelligence. This then is just another nickname for bodily-kinaesthetic intelligence: 'the capacity to solve problems or to create products using your whole body, or parts of your body' Gardner (2006a, p. 35). Furthermore, engineering directly builds on applied mathematics and physics, including the laws that rule in these domains. Indeed, 'the engineer is convinced that he can capture the essence of life in a net of numbers and logic' (Koen, 2003, p. 69). This notion becomes very visible in the typical curriculum in engineering education programmes including maritime design, which resist including HCD and HF aspects within their curriculum.

The published literature lacks information on the presence of HCD and HF related topics within the maritime design curriculum, with the sole exceptions of efforts taken by Chalmers University of Technology, Sweden, and University of Southampton, England. The Maritime Human Factors Group at Chalmers University conducted a four day short course from 2008 to 2013 on HF for naval architecture students which delivered basic knowledge within the field of maritime HF[3]. The University of Southampton provided an optional HF module to fourth year ship science students, open to any engineering student at the university[4]. However, the short courses and optional modules was not a sustainable solution since the topics were not systematically integrated within the education system of the students. According to Myles (2016), a Ship Science undergraduate from University of Southampton, most attending students in this HF module were from the branches of mechanical engineering, aeronautical engineering, and the acoustical engineering programmes, rather than from

[3] Prof. Margareta Lützhöft, Research leader in HF, Chalmers University (2006-2013), Personal communication, July 9, 2014

[4] Dr Jonathan Earthy, Human Factors Coordinator, Lloyd's Register Global Technology Centre, Southampton, Personal communication, February 10, 2016

ship design. She describes a lack of awareness and understanding in undergraduates about HF and HCD concepts in the following way;

> 'I had actually never heard of the term human factor. During my course when we had a go at concept design we kind of hit on the subject when trying to fit seats into a ferry, and were trying to think how much space they needed and what was the minimum size a toilet can be. If we had applied human-centred design, we would not have been worrying about this after we had our hull form. The design would have been started by looking at the user and what they need and how much space they would take up' (Myles, 2016)

She commented that when she started writing a document to help ship science students understand HF in ship design, she had a chance to discuss it with a fellow student. Surprisingly that student had also never heard of HF and said that it all sounded a bit psychological and complex to him. She reported that another student gave her a very blank stare about what she was talking about. Then she decided to discuss it with an aeronautical engineering student who was not part of the marine industry, and their view was quoted as follows in her article.

> 'I think we make sure the humans fit in and can reach the controls. Is not it obvious, does not it already exist?' (Myles, 2016)

At the end of her article she concludes:

> 'We are quite behind in looking at human factors. The seafarers want the human factor to be addressed and the naval architects are unclear on what really needs to be done' (Myles, 2016)

Consequently, in the absence of HCD aspects within the maritime design curriculum, design ideas do not adequately come to include an understanding of the operational environment, nor do they come to address practical challenges faced by seafarers. In this way industry design innovations may just end up with the tag of another poor design (Hemmen, 2008; Miller, 1999). Therefore, studies of Petersen (2012), Mallam (2016), and Myles (2016) suggested an early intervention during the maritime design education as the essential first step for increase the inclusion of maritime HF in ship design. Petersen (2012) further discusses issues around the delivery of usability design leaders to the maritime industry. He questioned how many of these are in existence, and from where we can get a fresh supply (Petersen, 2012, p. 178). He believes that there is a significant need for educational change in universities and academia in order to producing such team leaders and that they need a seasoning of practice, and the ability to survive in an industrial environment for long enough to earn the required respect and experience to go on to have an influence (Gulliksen et al., 2006). The published literature however lacks studies that have been done to integrate HCD knowledge into maritime education.

Eventually, it is identified that there is a great need to have HF, HCD disciplines taught in a systematic, engineering-oriented fashion by integrating them in the maritime education, in order to transform the current situation. It would ensure that graduates are equipped to enter the workforce as practicing maritime designers who have a wider range of skills, both technical as well as non-technical, and have capabilities and knowledge for the designing of ships that are really usable. Furthermore, students should be encouraged to carry their knowledge forward into their future design teams so that these concepts can be fully implemented in future maritime designs. This research study has thus been initiated to integrate HCD knowledge into maritime design education and to motivate students to utilise their knowledge in the design process. The next chapter of this thesis describes the teaching framework that was constructed to impart HCD knowledge into maritime design education.

Chapter 3

Pedagogical framework and research context

This chapter presents the pedagogical framework and research context of this study. Firstly, it reviews the existing literature of recent initiatives to develop a holistic design engineer through a holistic engineering education. It then reviews the literature of student-centred pedagogies and related theoretical foundations that were used to construct the pedagogical framework for this study. It then explains the operationalisation of the framework to integrate HCD knowledge into the maritime education through undergraduate design projects.

3.1 Engineering design projects – path to holistic engineering education

The most significant challenge for integrating HF and HCD content into engineering education is that discussions about humans and non-technical aspects is unfamiliar to a discipline primarily grounded in mathematics and engineering (Gardner, 2006a; Koen, 1985). However, recent initiatives to develop holistic engineers have shed light on aspects that engineering education is largely lacking – the development of essential non-technical knowledge, interpersonal skills and team skills. The United States National Academy of Engineering (NAE) wishes to change the public perception of engineering by describing engineering as a profession that will solve human problems and thereby improve the lives of people (NAE, 2008).

Following a similar path, Fila et al. (2014) claims that people are central to engineering and, as such, holistic engineering education must be catalysed by having engineering students think about the people they will be engineering for and with, while meta-cognitively and socially developing both as a person and engineer. Based on the studies of Hynes and Swenson (2013) on the humanistic side of engineering education, Fila et al. (2014) offers a framework on engineering with people, engineering for people, and engineering as a person.

- Engineering with people – represents how engineering students collaborate within small teams both within and outside of their organisations and communities. Through the lens of ‘engineering with people’, engineering students find opportunities to involve user groups by speaking with them, observing them, and adopting their perspectives.
- Engineering for people – encompasses designing a product or system to serve user needs. Engineering students find opportunities to evaluate and include data and insights from users who have stakes in the solution.
- Engineering as a person – the engineering student is an individual with unique knowledge and skills. They must consider how these influence their scope and resulting design solutions.

Consequently, in order to integrate ‘engineering for, with, and as’ skills into engineering courses and programs, in turn leading to the development of a ‘holistic engineer’, Fila et al. (2014) emphasises the pedagogical strategies outlined below.

According to Fila et al. (2014), design project activities in engineering courses are considered as a most effective pedagogical approach to provide the skeleton upon which an instructor can integrate ‘engineering for, with, and as’ aspects. These authors propose integrating empathic design/HCD/UCD, social science, and humanities disciplines into the engineering design activities in order to transfer the non-technical methods based knowledge to design engineering artefacts. They recommend including a series of seminars on the mentioned topics. Furthermore, they suggest that choosing a problem for the collaborative project, and situating it within a specified context, presents an opening to powerfully introduce all three dimensions ‘engineering for, with, and as’. Fila et al. (2014), Leydens and Lucena (2009) and Grasso and Burkins (2010) suggest that within this collaborative problem solving, the instructor or lecturer may consider asking questions to let students think about the people they will be engineering for and with, such as ‘How do you know this will meet your users need?’, ‘How have you gathered input from your user throughout this process?’, and ‘Do you tend to talk or listen in your conversations with your client?’. In addition, asking students to work in teams, with clients, and users, immediately introduces opportunities to develop the ‘engineering with’ part of the framework. Through collaborative design project activities, students’ interpersonal communication skills may be developed, having a significant impact on the development of a ‘holistic engineer’ (Fila et al., 2014).

Rifkin (2010, p. 607) also states that collaborative learning improves ‘respect among all the players involved, a willingness to listen to others’ perspectives, being open to criticism and a desire to share knowledge, and being responsible for and accountable to the group as a whole.’

Engineering degree courses around the world have been increasingly recognising the multi-disciplinary nature of engineers’ work, and thus collaborative design project activities are part of their engineering courses (Dym et al., 2005; Koutsikouri et al., 2008; Mills & Treagust, 2003; Thomas et al., 2013; Thomas et al., 2006). Furthermore, some degree courses including mechanical, electrical, software design and industrial engineering have already taken steps to additionally integrate HCD knowledge into students’ design projects, and have shown that it contributes towards training students to become socially conscious design engineers.

As an example, Pastel et al. (2014) identifies that HF is not a subject traditionally taught in the Computer Science (CS) curriculum. According to these authors, the traditional CS education focuses on the computer (the machine), and the programs for the machine. Because the faculty was not introduced to HF in their education, studying users has no role in their discipline. The authors conducted a study to integrated HCD knowledge into students’ CS design projects. At the end of the study, they conclude that the students improved their skills and knowledge at implementing user interfaces with new technologies, and learnt the value of designing interfaces for satisfy the user needs. In addition, students learnt that their technical knowledge is insufficient to ensure a usable interface. Furthermore, this provided undergraduates with the opportunity to develop their skills to work effectively with users and HF professionals.

The next example is Oehlberg et al. (2015), who endeavours to teach HCD to mechanical, electrical, computer science, humanities, and molecular and cell biology students through a multidisciplinary design project. Along with in-class HCD activities, students also completed a short six-week design project. The authors conclude that the participant students valued the opportunity to become more familiar with their local design community while learning about HCD theoretical knowledge and the design approach.

Another example involves the Department of Mechanical and Industrial Engineering at Ryerson University who introduced a new unit, ‘Engineering Design Project’, intended to address perceived shortcomings in the mechanical engineering and industrial engineering undergraduate programs. The faculty members realised that there was very little literature on how HF and HCD can be embedded ubiquitously in the engineering design processes. However, they identified the design activities as an effective path to introduce HF and HCD knowledge (Fila et al., 2014). As a result, the ‘Engineering Design Project’ unit has become anchored on the concept of ‘human-centric engineering design’ (Salustri & Neumann, 2017). The unit continues to improve every year, and the latest publication demonstrates the students’ improvements in providing design solutions through the HCD approach (Salustri et al., 2017). Enrolment has increased significantly, by about 40% since the unit was first offered.

Maritime engineering courses also include design project activities as a significant part of the course, similar to those at many other engineering universities around the world (Australian Maritime College, 2004; Lee et al., 2013; Miller, 2003; Ocean University, 2002; Seoul National University, 2000; The University of British Columbia, 2000; Thomas et al., 2013; Thomas et al., 2006; University of

Southampton, 2000; University of Strathclyde, 2000). Nevertheless, it is noted that the application of HCD activities within maritime undergraduate design projects is virtually non-existent, yet critical for the work of a practicing ship designer. Thus it is recognised that, if the maritime students are introduced to maritime HF issues as well as the application of an HCD approach during their design projects, they could put it into practice and eventually it would help ensure that graduates are equipped to enter into the workforce with a wider range of skills in designing ships that are truly ‘usable’.

3.1.1 Engineering design projects and problem-based learning pedagogy

The roots of Problem-based learning (PBL) go back to the mid-1960s at the McMaster University medical school in Hamilton, Canada (Neufeld & Barrows, 1974). A common problem in medical education was that students had difficulty with first-year units such as anatomy, biochemistry and physiology. They struggled with these topics and became less motivated because they did not see the relevance of the issues discussed in these units for their professional futures (Barrows & Tamblyn, 1980; Schmidt, 1983). McMaster University medical school came up with an instructional format that used realistic medical problems that physicians have to deal with. Introducing ‘problems’ in a unit was not the innovative element here, but rather the moment that students were presented with these problems, namely as the starting point of the learning process before any other curriculum input (Barrows, 1996). It is assumed that Donald Woods of McMaster University medical school was the first to use the term PBL (Savin-Baden & Major, 2004). Since then, PBL has been implemented in numerous programs across many domains and at many educational levels on a world-wide scale. In addition, PBL is widely regarded as a successful method for institutions of engineering education worldwide (Brodeur et al., 2002; Brodie & Borch, 2004; Rhem, 1998; Vernon & Blake, 1993; Wilkerson & Gijselaers, 1996), especially for engineering design and research projects (Hadgraft, 2005; Mills et al., 2003; Perrenet et al., 2000; Tse & Chan, 2003).

Brodie et al. (2004) define PBL as a constructivist learning paradigm where small groups of students engage in cooperative learning and collaborative problem-solving in complex and authentic projects. In a PBL environment students learn through undertaking real-life problems. A problem, or challenge, is presented to a group in the same manner in which it would be presented in a genuine professional situation, and before any other instructions are given (Barrows et al., 1980). Students work with the problem, undertaking systematic enquiry, and the group is guided by a tutor or facilitator. Working in a PBL environment is understood to be exciting and interesting for engineering students since PBL provides them with opportunities to consider how the facts they acquire relate to a specific problem; and the projects are ideally related to future professional practice (Loyens et al., 2011). Consequently, PBL is designed to foster several other desirable learning outcomes, namely to help students (1) construct an extensive and flexible knowledge base, (2) become effective collaborators, (3) develop effective problem-solving skills, (4) become intrinsically motivated to learn, and (5) develop self-directed learning skills (Norman & Schmidt, 1992).

The first learning outcome should enable students to retrieve and use information when needed. Activating prior knowledge through a problem discussion within the group is seen to set the stage for the to-be-learned information, facilitating elaboration and increasing retention. The second learning outcome is achieved by working together in groups, with colleagues, clients, and users of the design. This enables students to develop interpersonal skills and learn how to become good collaborators, learning to contribute to the discussion in an open and clear way; come to an agreement about the learning issues and their answers; and resolve possible inconsistencies in their findings (Hmelo-Silver, 2004). Since the problem is the starting point, students are expected to learn to develop problem-solving skills, which is the third learning outcome. PBL aims to teach students how to analyse the problem at hand, to assess the importance of various pieces of information, and to decide which information should be used to understand, explain, or solve the problem and plan subsequent study actions (Barrows, 1996). With regard to PBL's fourth learning outcome to foster intrinsic motivation to learn, working on problems is believed to be engaging and interesting for students, since they present realistic situations, usually related to future professional practice. Besides working on meaningful tasks, it was also identified that the control that students have over their learning would also motivate (Bandura, 1997). The notion of control prefaces the final goal, namely developing self-directed learning skills. This refers to 'the preparedness of a student to engage in learning activities defined by him or herself, rather than by a teacher' (Schmidt, 2000, p. 243). Therefore, when considering the outcomes in terms of learning and development, PBL which is described as a newly recovered style of learning (Rhem, 1998; Savery, 2006; Stanford Graduate School of Education, 2014).

Studies in the 1990s suggested that the engineering programs and its graduates were generally deficient in addressing the concerns of society (Mills et al., 2003). Some of the key concerns, as listed in Mills et al. (2003), included the following:

- Engineering curriculum tend to focus on engineering science and technical units without providing sufficient integration of non-technical knowledge
- Programs do not provide sufficient design experiences
- Graduates lack communication skills and teamwork experience
- Programs need to develop awareness amongst students of the social, environmental, and humanities issues
- Teaching and learning strategies in engineering programs is out-dated and needs to become student-centred

With acceptance of these concerns, engineering programs starting in the 1990s realised a need for curriculum change. PBL was adopted by many engineering design programs as an approach to help graduates learn the skills required by their employers, and to address many of the concerns listed above (Brodeur et al., 2002; Christie & de Graaff, 2017; McLernon & Hughes, 2006; Mills et al., 2003; Perrenet et al., 2000; Rhem, 1998; Tse et al., 2003).

The use of PBL in engineering design programs has been reported by several authors. One of the well-known applications was Don Woods in the chemical engineering program at McMaster University (Woods et al., 1997). With a strong tradition of PBL already developed in the medicine program at the same university, the department of chemical engineering decided to implement it in their program in the early 1980s. The PBL approach, as implemented in chemical engineering, is used in a senior design project unit. It is carried out in class sizes of 20 to 45 with one faculty member. To make this work successfully, Woods uses a series of workshops that have been embedded into four of the chemical engineering units spread through the years of the program. These workshops help students to develop collaborative problem-solving, interpersonal skills, and team skills, which enable them to undertake the self-directed PBL process under the faculty members' guidance.

At Monash University, Australia, PBL has been introduced into several units in the civil engineering degree through the initiative of Roger Hadgraft (2005). He has incorporated PBL into a third year unit in systems design; a post-graduate unit in water supply system design (Hadgraft, 1992); and a fourth year unit in computer applications (Hadgraft, 1997). Some of the other applications of PBL in engineering design courses/design projects that have been reported include:

- Design in second year Mechatronic Engineering at Curtin University, Western Australia (Rogers & Morgan, 1998)
- Water-system Design Engineering in fourth year Civil Engineering at Griffith University, Queensland (Lemckert, 1998)
- Hydraulic System Design in junior/senior level at Pennsylvania State University, Pennsylvania (Johnson, 1999)
- Ship design, small craft design, and offshore system design in final year Maritime Engineering at Australian Maritime College (AMC), University of Tasmania, Tasmania (Thomas et al., 2013; Thomas et al., 2006)
- Augmented Reality in higher maritime education in La Laguna University, Spain (Luis et al., 2013)
- Product design development projects in fourth year Mechanical Engineering at Massey University, Auckland, New Zealand (Shekar, 2014)
- Structural and Civil Engineering projects at Aalborg University, Denmark (Guerra, 2015)
- Future space mission design course at School of Aerospace, Royal Melbourne Institute of Technology University, Melbourne, Australia (Richard et al., 2017)

Ultimately, the collaborative problem-solving nature of this PBL pedagogical approach allows integration of essential non-technical knowledge, interpersonal skills and team skills. Furthermore, the desirable learning outcomes of PBL presents an opening to train engineering students think cognitively about the people they will be designing for and socially developing both as a person and engineer (Fila et al., 2014). Thus, PBL has become both a holistic teaching/learning method and a pedagogical philosophy.

3.2 Problem-based learning pedagogy and its theoretical basis

At first PBL lacked a theory of how it worked and what was happening during the process. For example, Spaulding and Cochran (1991) describe using the PBL approach simply as a pragmatic means of improving the educational experience. Researchers rapidly took an interest in PBL, and the theories and methods applied to PBL have reflected the prevalent theories and methods of the time. Many researchers applied cognitive psychology to PBL and used the experimental approach consistent with this discipline (Norman et al., 1992). Others borrowed statistical approaches from disciplines such as epidemiology to try and quantitatively compare PBL with the traditional educational methods (Baxter, 2000).

A theoretical perspective on PBL is offered by constructivist epistemology, a developed area of learning theory rooted in the work of Lev Vygotsky (Vygotsky, 1978). Vygotsky believed strongly that social interaction plays a central role in the cognition development of the learners. The central principle of constructivism idea of Lev Vygotsky is that knowledge is ‘constructed’ by the learner’s cognitive activity by continuous interaction and participation in the social community of which the learner is a member. Learning takes place through active participation in social interactions with more knowledgeable individuals while engaged in relevant meaningful activity. Learners receive assistance through interactions characterised by such activities as directing, modelling, questioning, and providing cognitive structuring and feedback, until they are able to perform without assistance or guidance (Hendry et al., 1999).

According to Vygotsky's Zone of Proximal Development (ZPD) theory, which is developed based on his constructivism idea, ZPD is 'the distance between the actual development level as determined by independent problem-solving and the level of potential development as determined through problem-solving under guidance or in collaboration with a more knowledgeable other' (Vygotsky, 1978, p. 86). Vygotsky called this more knowledgeable other/more capable peer the instructor or near peer, whose role it is to help learners reach their ZPD by assisting on the path.

Therefore, the constructivist ZPD theory by Lev Vygotsky provides a theoretical rationale for PBL in two ways. First, PBL places learning within a social context. Learners meet with a tutor/facilitator or project stakeholders to work on meaningful problems related to their chosen area of practice. They work collaboratively as they discuss issues, and assist each other to make connections between new ideas and prior knowledge, creating new meaning as they complete their tasks. Second, the role of facilitators and students in PBL are congruent with the constructivist paradigm in which more capable persons assist, but do not dominate, the activities and experiences of the learner (Hendry et al., 1999; Rideout, 2001).

Furthermore, Vygotsky's ZPD is commonly referred to as the theoretical underpinnings of scaffolding, developed by Wood et al. (1976) and this association has been recognised by scholars in education (Davis & Miyake, 2004; Harland, 2003; Nordlof, 2014; Puntambekar & Hubscher, 2005; Verenikina, 2003; Wass, 2012). Scaffolding represents the support which is given to a learner in order for them to attain a goal or engage in a task otherwise out of reach (Davis et al., 2004; Nordlof, 2014). For example, as the learner masters each element of the task, the scaffolding may be removed and gradually more control is passed to the learner. Therefore, 'What is the ZPD today will be the actual developmental level tomorrow' according to Vygotsky (1978, p. 87). Hence, through successful scaffolding, the outer boundary of the ZPD can eventually become the new independent level of the learner (see Figure 3.1). Therefore, it can be concluded that Vygotsky's ZPD and the scaffolding concept provides an appropriate explanatory framework for PBL implementation.

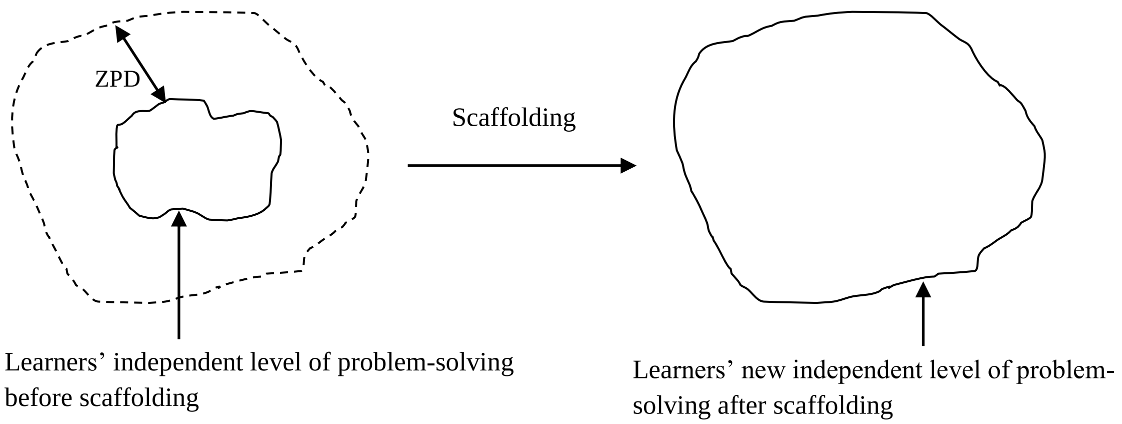


Figure 3.1: Scaffolding learners from independent level to ZPD to a new independent level of problem-solving.

3.3 Peer-led team learning pedagogy and its theoretical basis

Peer-Led Team Learning (PLTL) is a pedagogical approach to provide small group instruction which can be employed in conjunction with the traditional lecture components of undergraduate courses now so deeply entrenched in university systems (Gosser et al., 2001). The PLTL approach was developed in the early 1990's (Gosser & Roth, 1998) and implemented in science, technology, engineering and mathematics (STEM) courses (Hewlett, 2004; Tenney & Houck, 2003; Wamser, 2006) in which peer-led workshops are an integral part. Under the PLTL model, undergraduate students who previously have done well in the class are recruited and trained as workshop leaders -peer leaders- who carefully apply their knowledge and guide the team members to solve problems. Thus peer leaders are like mentors who assist someone in making an important transition, learning a new skill, or facing a new challenge. Furthermore they ensure that the team members engage with the materials, and with each other; in this way, they help to build commitment and confidence (Gosser et al., 2001). Peer leaders work collaboratively with the unit instructor to facilitate group problem-solving after being trained in the content of the particular unit (Gosser et al., 1998). Peer leaders are not experts in the content, nor are they expected to provide answers to the students in their workshop groups. Rather, they guide and mentor students to develop their own understanding of concepts. Instructors are available to prepare peer leaders for facilitation. PLTL offers active learning opportunities for students in small groups of four to six students and creates leadership roles for peer leaders that are appropriate for their stage of development (Eberlein et al., 2008; Zonoozi et al., 2012).

According to Gosser et al. (2001), evaluations of PLTL programs have resulted in the following set of critical components for a successful PLTL implementation:

- A weekly one to two hour peer-led study-group sessions that is integral to the unit and coordinated with the other elements of the unit
- The unit instructor is closely involved with selecting materials and training peer-leaders
- The peer-leaders are well trained, with attention to both content and leadership skills
- The PLTL problems are challenging at the appropriate level for students, integrated with other components of the unit, and designed to encourage active and collaborative learning
- Organisational arrangements (size of group, space, noise level, time) are appropriate to promote productive discussions
- The participating departments and the university administration encourage innovative teaching and provide sufficient logistical and financial support for PLTL

In addition, the impact of PLTL on students, peer leaders, faculty, and institutions has been assessed and evaluated in various educational environments (Gafney & Varma-Nelson, 2007; Hockings et al., 2008; Lewis & Lewis, 2005; Tien et al., 2002) and it has been identified that the participants in PLTL implemented classes earned 14% higher grades than those in non PLTL classes.

Although the ultimate goal of peer leader programs is to serve and support fellow students, the power and potential of these programs also lie in their mutual benefit to those students serving in the leadership roles. According to Shook and Keup (2012), peer leaders will hone abilities that have been identified as twenty-first century learning objectives for colleges, that are also highly desirable skills for employers. Those abilities are self-directed thinking, leadership skills, oral communication skills, intercultural skills, civic engagement, teamwork, contextual teaching skills and critical thinking. For example, Harmon (2006) found that the peer mentors who serve first-year students report increased confidence in their ability to manage group dynamics and facilitate learning. Finally, peer leadership experiences not only facilitate the development of multiple applied skills but also are a forum for the integration of these different skills.

Although PLTL also has constructivist underpinnings, it is motivated by specific concepts in learning (Gosser et al., 2001). The most relevant theoretical basis for PLTL is found in the work of Lev Vygotsky, particularly the ZPD, and the metaphor of scaffolding developed by Wood et al. (1976). As explained in the Section 3.2, the two critical components in Vygotsky's ZPD theory are: (1) an individual who has a higher level of ability (a more knowledgeable other) than the learner with respect to the particular idea that needs to be learned; and, (2) tasks are designed to push the learner to a reasonable expectation of achievement or understanding, by providing appropriate scaffolding that is easily removed as learning gains are achieved. This is where the connection appears between PLTL pedagogy and Vygotsky's ZPD occurs with the metaphor of scaffolding. Within the PLTL pedagogy, it can be seen that the peer leader stays within a group, promotes group interaction and provides suitable scaffolding to solve complicated problems that team members cannot solve on their own, like a more knowledgeable other does according to Vygotsky's ZPD theory. Hence PLTL draws students into their ZPD by having them work together on problems in groups in the instructor's absence, but with the help, guidance, or collaboration of a more capable peer. Therefore, it can be concluded that Vygotsky's ZPD and the scaffolding concept provide a theoretical rationale for PLTL implementation.

3.4 Connections and overlaps between PBL and PLTL pedagogies

As discussed in Sections 3.2 and 3.3, the following points summarise the connection between the two student-centred pedagogies, PBL and PLTL, and Vygotsky's ZPD theory and the concept of scaffolding:

- Both PBL and PLTL have constructivist underpinnings found in the work of Vygotsky (1978), particularly the ZPD theory, and the metaphor of scaffolding developed by Wood et al. (1976)
- PLTL situates students in their ZPD as does PBL
- Both PLTL and PBL use students working together in groups, and therefore highlights the social aspects of learning
- The nature of problems used in PBL and PLTL units are complex, open ended, real world problems
- Both the cooperative learning strategies and collaborative problem-solving methods to solve complex issues can be found in PBL as well as in PLTL
- In PBL a tutor or facilitator guides the group in collaborative problem-solving so as to reach their ZPD
- In PLTL peer leader guides the group in collaborative problem-solving so as to reach their ZPD
- PLTL supplements but generally does not replace lecture time with group work sessions

The connections between these pedagogies and theoretical footings, as well as overlaps discussed in this chapter are illustrated in Figure 3.2.

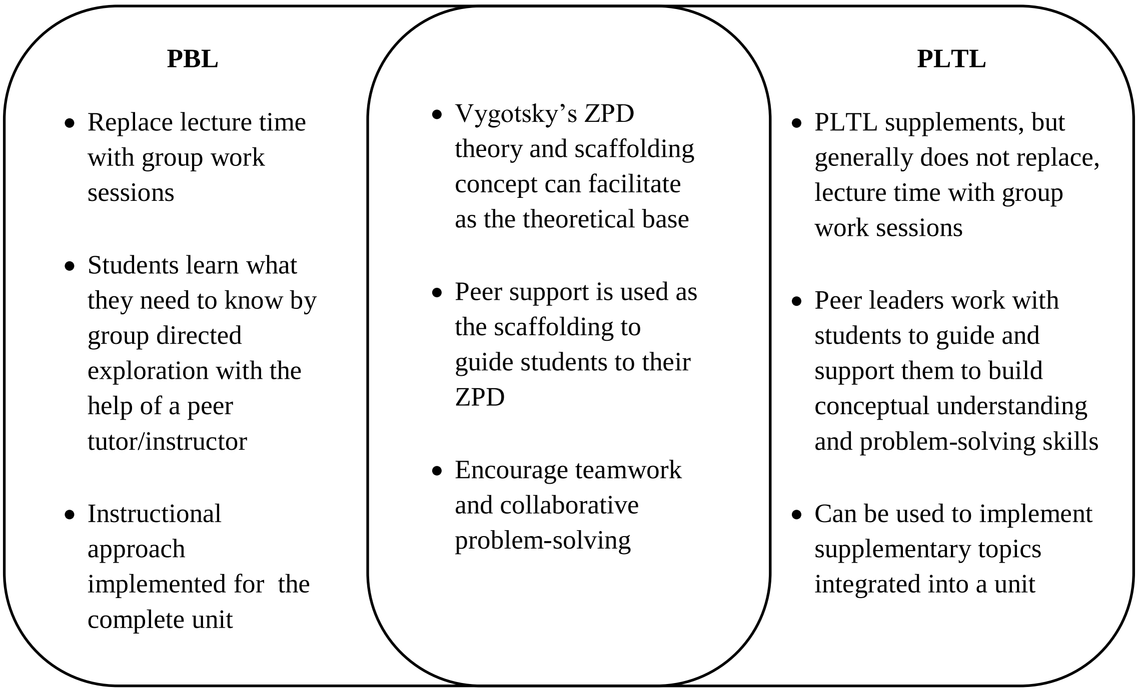


Figure 3.2: Connections and overlaps between PBL and PLTL pedagogies.

Eventually, PLTL with its basis in constructivism and the social aspects of learning as indicated by Vygotsky’s ZPD, situates students in their zone of proximal development, just as PBL, by presenting problems that they cannot solve easily on their own, but can solve by interacting with peer members of the team or facilitators. Therefore, the student-centred pedagogical approach of PBL as well as PLTL can be effective at improving collaborative problem-solving.

3.5 Pedagogical framework

Based on the understanding developed through the above sections, I constructed a pedagogical framework. The framework connected peer-led team learning (PLTL) pedagogy with a problem-based learning (PBL) pedagogy based maritime design project unit, in conjunction with associated theoretical foundations; Vygotsky’s zone of proximal development (ZPD) theory and the scaffolding concept (see Figure 3.3).

This pedagogical framework is constructed in order to:

- Disseminate HCD knowledge into maritime design undergraduate projects
- Encourage, facilitate and guide maritime design students to learn HF and HCD and apply their newly acquired knowledge during design projects
- Create skilful and unique maritime HCD leaders who can facilitate and guide their colleagues and carry forward the knowledge into their future design teams, through adopting the PLTL approach

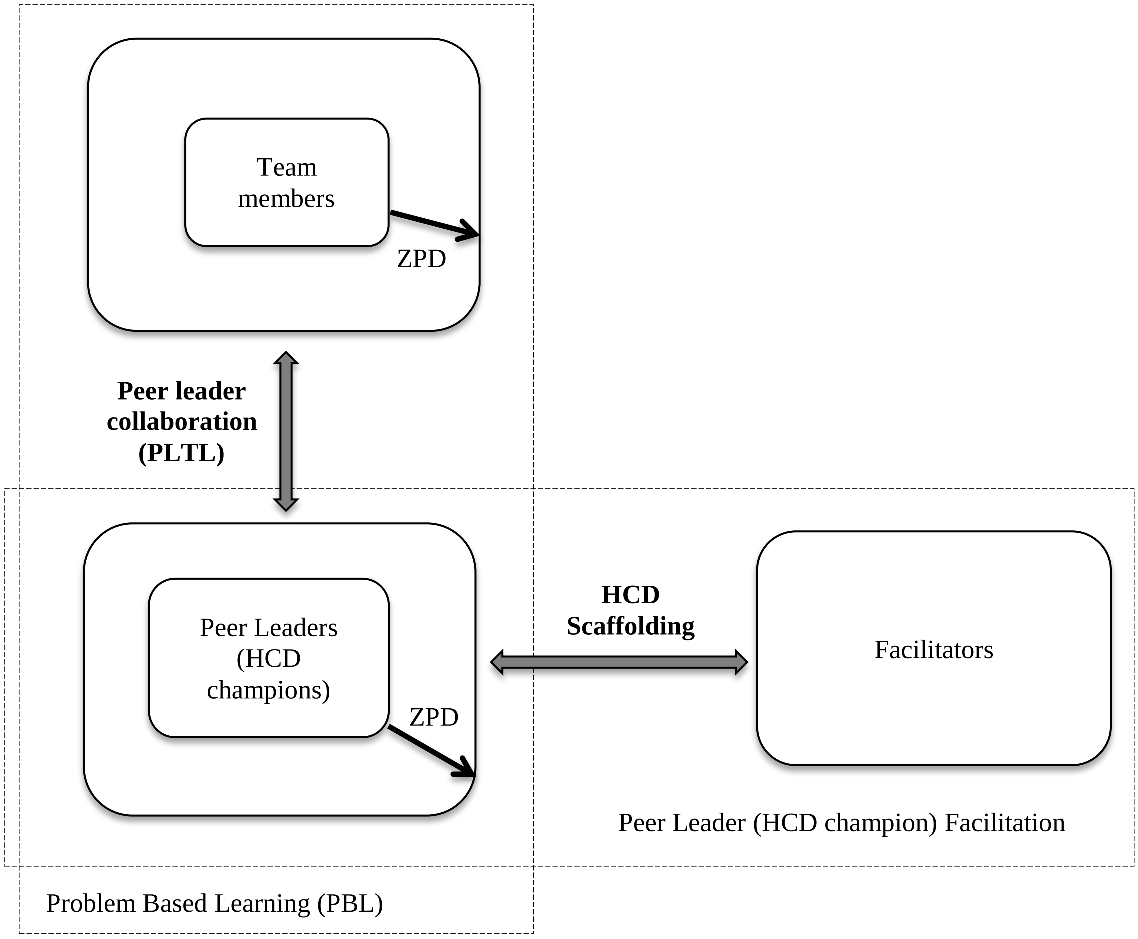


Figure 3.3: Pedagogical framework: constructed by linking PLTL pedagogy with PBL-driven design project unit in conjunction with associated theoretical foundations, which are Vygotsky's ZPD and scaffolding concept (Abeysiriwardhane et al., 2016).

As illustrated in figure 3.3, the framework consists of three parties: peer leaders, design project team members, and facilitators. Peer leaders are volunteer students from each design project team with a high level of motivation in learning and applying maritime HF and HCD into the design process and are ready to train and stay within the group as a more capable peer in maritime HCD. I call these peer leaders 'HCD champions' within this framework. Design project team members generally consist of four to six students working with the HCD champions within the PBL environment. Facilitators are the researcher, HF specialists, and field experts; experienced seafarers from the maritime industry. Following the PLTL pedagogy, HCD champions have to be a group of students who have done well in the discipline in previous years. However, the researcher cannot invite such students if such topics or program have not been delivered to these students in previous years. Therefore, a HCD champion facilitation has to be planned carefully to train and supervise the HCD champions in small-group collaborative-learning sessions.

Within this framework, the HCD champions are thereby working collaboratively with the facilitators to become more capable peers through planned HCD knowledge dissemination activities. I call this a 'HCD scaffolding program'. This facilitation can be considered as scaffolding the path of HCD education of HCD champions to reach their ZPD potential in maritime HCD. Also during this HCD scaffolding program, HCD champions are motivated to work with their respective design project teams within the PBL environment focusing on usability aspects of their designs while ensuring the effective dissemination of HCD understanding to the team members, so as to, in turn, draw the team members towards their ZPD in maritime HCD. Furthermore, HCD champions are requested to provide authentic feedback and suggestions to improve and modify the HCD scaffolding program.

The HCD champions are supervised by facilitators to guide the team members in solving HF issues within the design, ensuring that team members engage with the study materials, learn new skills, and face new challenges. However, the facilitators do not often attend collaboration sessions of the HCD champions with their team members because their presence may have an effect on the student to student interactions. Although the team members do not have the direct connection with the facilitators that the HCD champions do, the whole design team may participate in group sessions such as consultation sessions and group workshops. Within this framework, HCD knowledge dissemination flows from the facilitator to the HCD champion and then through to the team members.

Through the HCD knowledge dissemination via this framework, the HCD champions and their team members should be able to learn: a range of skills that are important for maritime designers to design usable ships and systems; application of good ergonomic practices in the design process; knowledge of what needs to be considered in a user centred design process; and knowledge of industry rules, regulations and guidelines impacting tor guiding the human factors in design. Most importantly, as explained in the Section 3.3, the HCD champions have the opportunity to enhance their skills by assisting their team members and working collaboratively with the facilitators. Consequently, this teaching framework could shape some undergraduates into HCD champions for the maritime domain to influence others and spread their knowledge into future design teams so as to create a positive effect on future designs. Therefore, this framework extends the capabilities of PLTL and PBL pedagogies, and theoretical foundations of those, by way of introducing the ‘HCD champion concept’, to integrate maritime HCD knowledge into maritime design education.

3.6 Research context

The Bachelor of Engineering (BE) degree courses at Australian Maritime College (AMC), under the department of the National Centre for Maritime Engineering and Hydrodynamics, facilitates future maritime designers to conduct their studies in best teaching and research facilities. AMC provides the following four-year, full-time Bachelor of Engineering degree courses: Naval Architecture, with specialisations in ships and underwater vehicles or yachts and small craft; Ocean Engineering, with specialisation in ocean and subsea structures or marine aquaculture; and Marine and Offshore Engineering, with specialisation in offshore systems or marine systems. Like many maritime institutions and universities around the world, AMC also significantly considers that maritime engineering graduates require a wide range of skills, competences and knowledge in order to design modern marine vehicles, structures and systems (Thomas et al., 2006). Therefore a major learning outcome of the maritime engineering degree course at AMC is the ability to successfully undertake a yearlong design project which helps ensure that graduates are equipped to enter the workforce as practicing engineers (Thomas et al., 2013).

Within this unit, the students undertake a two-phase design process consisting of an initial concept building stage followed by a preliminary design phase. The initial concept building phase focuses on team building, project planning, and decision making with limited design activity (Thomas et al., 2013). This allows team members to undergo initial team-building phases like forming and storming (Tuckman, 1965) whilst allowing facilitators to monitor the team development. Project teams consist of four to six students from the three degrees mentioned above and they work in a design workshop environment that runs as one full-day session per week throughout the year. Faculty members or industry representatives provide design tasks to these teams. Following the PBL approach, faculty members act as facilitators rather than supervisors and they monitor team progress at different stages of design. The practical nature of this unit is also important since by encouraging students to actively get involved in solving problems, it allows them to develop their teamwork skills as well as system engineering proficiency and communication skills (Thomas et al., 2013).

Yet, similar to most maritime engineering degree courses, AMC degree courses suffer from a lack of HCD components within the four-year study period (Abeysiriwardhane et al., 2014). This is further supported by the author's discussion with faculty members who stated that the first three years of this course uses the traditional lecture-tutoring teaching approach and is focused on the technological field (see Chapter 5, Section 5.1). However, if students were introduced to maritime HF issues as well as the application and benefits of an HCD approach to the maritime design process, they could put it into practice during their design project unit. Eventually it would help to ensure that graduates are equipped to enter into the workforce as holistic maritime designers, with a wider range of skills, capabilities and knowledge to design ships that are really 'usable'. In other words, they would better be able to answer the question that should confront all maritime designers according to Rasmussen (2005): 'How can we design a usable ship taking user requirements more completely into account?' Therefore, this PBL-driven design project unit at AMC was selected as a suitable juncture to find potentials and opportunities to integrate HCD knowledge into maritime design education. The students who enrol in the design project unit are selected as the participants of this research study.

Chapter 4

Methodology

This chapter presents an overview of the Action Research method, which is used for operationalisation as well as studying the effectiveness of the constructed pedagogical framework and HCD knowledge dissemination activities during this study. It then discusses the tradition of Action Research used in this research study. Furthermore, it includes the positionality of the researcher, methods used for data collection and analysis, quality indicators of research method, and the ethical framework followed in this research study.

4.1 Introduction to Action Research

The principle behind Action Research (AR) is that, as the name implies, it combines the dual aims of 'action' and 'research'. AR can therefore be identified as a research methodology which integrates 'action' which is about problem solving or improving the current practice in some community, program or organisation, and 'research' which is about developing an understanding of the effectiveness of action (Coghlan & Brannick, 2005; Herr & Anderson, 2005; Kemmis & McTaggart, 1988; McNiff, 2014; McNiff & Whitehead, 2003, 2006; Wadsworth, 1998). In other words, it is a process of investigating how action contributes to problem solving and improvement of current practice, and then becomes a process of knowledge creation (McNiff et al., 2003; Stringer, 2007); offering explanations for how and why this has happened. Hence, 'action' and 'research' concepts always work together in AR practice. It is helpful however to look at them independently so as to distinguish their individual contributions, and to understand the nature of their relationship within any given research study.

Action researchers have described the process of AR in different ways. The significant feature of AR that everyone agrees on is that it operates in cycles where similar steps recur within a cyclical process (Checkland & Holwell, 1998; McNiff et al., 2003). The pioneering representation of AR was by Lewin (1946), whose model was composed of sequential steps that included planning, fact-finding, execution, and analysis. According to him, planning began with a general idea or a difficult problem that required a solution. This was then followed by further fact-finding, or reconnaissance of the general idea or problem, resulting in an overall plan of how to solve the problem or to improve the situation. These planned actions were to be implemented and monitored to evaluate the effectiveness of the actions, which then lead to modifications of the overall plan in order to proceed on to the next action cycle.

Elliot's (1991) AR model is developed based on Lewin's and it allowed researchers to revise the general idea at each action cycle. In this model the first step was to identify and clarify the general idea that the researchers wished to change or improve. During the second step, i.e. the reconnaissance step, the facts of the situation were described and explained on the basis of a critical analysis of the context in which those facts had arisen. Constructing the general plan is the third step within this model. The fourth step included decisions about the courses of action to be implemented, and how both the process of implementation and its effects were going to be monitored. Then the researcher shifted from monitoring into a period of reconnaissance to gather ideas about the effectiveness of the actions in order to revise the general idea before stepping into the next cycle of the research study (Elliot, 1991).

Sagor's (1993) model of AR has five sequential steps: problem formulation, data collection, data analysis, reporting of results, and action planning. Researchers identify the issues to be studied in the first step. Participants are then involved in the next step through collecting data and assembling it. He believes that data collection is 'the heart of the five step process' (Sagor, 1993, p. 10), that enables a researcher to look at the issue through different viewpoints. During the next step, the researchers analyse the data and drew up conclusions. These conclusions are then to be reported and communicated within the research community. During the last step, decisions are made on how to use the research findings to plan and implement improvements.

Another representation of AR by Coghlan et al. (2005), whose model is comprise of a number of sequential steps which include diagnosing, planning action, taking action, evaluating the action, which then lead to further planning. Diagnosing involves naming what the issues were, however provisionally, as a working theme on the basis of which action is to be planned and taken. Once the problem is diagnosed it leads to planning actions within a framing of the issue. Then the plans are implemented and interventions are made. Afterwards, the outcomes of the action, both intended and unintended, are examined to establish further planning.

Deakin's model of AR by Stephen Kemmis and his colleagues (Carr & Kemmis, 1986; Kemmis & McTaggart, 1987; Kemmis et al., 1988) comprise of the four steps of planning, acting, observing, reflecting and re-planning. The initial cycle of these steps lead to a second cycle in which the reflections of the initial cycle actions and its findings are used to determine the plan for the next cycle. As these action cycles progressing, a greater understanding is developed through continuous refining of methods, data and the results (Kemmis et al., 1987). According to these authors key steps within the AR process are; reviewing current practice, identifying an area that needs to improve, imagining a way for the improvement, trying the imagination, finding evidence for the improvement, modifying the plan in view of the findings and continuing with the action, finding evidence of modified plan, and continuing until satisfy with the results of the research study.

Eventually through different AR models, it becomes clear that the cyclical form of AR always involves a continuous process of identifying an issue, planning an action, taking that action, reflecting on it, and then re-planning it in new ways in light of results. In this way it ultimately becomes a cycle of action and reflection. Action implementation, data collection, data analysis, and interpretation may occur simultaneously within an AR, due to its nature as action and reflection. AR should be undertaken in a systematic and reflective way, to ensure that important steps in the process are not overlooked. The effectiveness of the actions can be evaluated through qualitative and quantitative data gathering tools such as interviews, questionnaires, document analysis, field notes, photographic evidence, video recordings, checklists, inventories, and case studies (Elliot, 1991; Hopkins, 1985; Kemmis et al., 1987; Kemmis & McTaggart, 2005). A number of these techniques and data analysis are further reviewed in Section 4.5 and 4.6 of this chapter.

AR methodology is characterised as a participative process (McNiff & Whitehead, 2002). However, the term 'participation' covers different levels of engagement. According to Grundy (1982), Carr et al. (1986), Mamlok-Naaman and Eilks (2011) as well as Masters (1995), participation can vary from the lowest level of participation to the highest level, which is called the emancipatory level of participation. At the lowest level, participants are identified as representatives who help the researcher during a research study. They agree to provide a service to the researcher. They can help to produce data but they themselves are not producing data (Biggs, 1989; Cornwall & Jewkes, 1995). At the highest level of participation, participants engage with the researcher as collaborators who are involved in research design and the proposed research methods, they facilitate some of the research activities, and importantly, they review and evaluate the process as a whole. Furthermore, they may take joint ownership of the research process (Grundy, 1982; Kindon et al., 2007). Since there are many possibilities of participation levels between the least and the emancipatory, there is no concrete way of defining them for each and every research study. One good example is the AR project conducted by Watters et al. (2002) to improve the effectiveness of teaching and learning for part time teachers at the Queensland University of Technology, which progressively mobilised people from the least participatory level to the emancipatory level throughout their study.

Rasmussen (2004) notes that action researchers distinctively take different roles within their study. Through active and careful involvement in the context of the investigation, they are not scientific advisors, but they assume roles including that of ‘facilitator’, ‘process-planner’, ‘analyst’, ‘evaluator’, ‘co-ordinator’, ‘friendly outsider’ or ‘change agent’ (Rapoport, 1970). However, according to Herr et al. (2005), researchers can play six different roles in relation to the participants. These are:

- Insider studying own self or practices
- Insider in collaboration with other insiders
- Insider(s) in collaboration with outsider(s)
- Reciprocal collaboration
- Outsider(s) in collaboration with insider(s)
- Outsider(s) studying insider(s)

These positions are discussed in Section 4.4 of this chapter where I explore my own position in relation to the research participants of the current study. Researcher positionality however does not fall into a neat category and might even shift during any given study (Herr et al., 2005). Researchers will have to figure out the nuances of their position themselves with regards to their setting and participants. For instance, Ospina et al. (2008) drew on Herr et al. (2005)'s typology of positionality to describe their research. They discovered that their position varied from ‘insider in collaboration with outsiders’ to ‘reciprocal collaboration’, to ‘outsiders in collaboration with insiders’ throughout the course of their research.

Furthermore, there are a multitude of subcultures in AR: Action Learning (Revans, 1980), Action Science (Argyris et al., 1985), Classroom Action Research (Dadds, 1995), Participatory Action Research (Carr et al., 1986), Reflective Practice (Schön, 1983), and Autoethnography (Bochner & Ellis, 2002), just to mention the more prominent ones. There are different viewpoints among these traditions about why and how AR should be undertaken, and these are discussed in detail in Section 4.3 of this chapter.

In addition, it is also significant to determine whether the knowledge generated through AR methodology is valid or trustworthy. According to Herr et al. (2005), quality, goodness, validity, trustworthiness, credibility, and workability have all been suggested as terms to describe criteria for good AR. The term validity (Campbell & Stanley, 1963) is preferred by positivists, and trustworthiness (Guba & Lincoln, 1989; Lincoln & Guba, 1985) is preferred by naturalistic researchers. AR criteria of validity and quality are discussed in detail in Section 4.7 of this chapter.

Research involving human subjects (or ‘participants’, in the current terminology) requires respect for ethical issues by obtaining approval from relevant authorities. Hence, AR methodology requires an understanding of the ethical framework, which is used in a particular context (Coghlan et al., 2005; McNiff et al., 2003). Such ethical principles typically focus on how the action researcher works with participants. Some authors have identified ethical issues that the action researcher needs to consider and resolve, including identity, data protection, ensuring participants the right to deny or discontinue participation, and getting permission to use information for publishing (Coghlan et al., 2005; Herr et al., 2005; McNiff et al., 2003, 2006). Therefore, the ethical framework for this study is explained in Section 4.8 of this chapter.

In summary, AR is a research methodology which combines ‘action’ (what I do to solve an issue or to improve current practice), and ‘research’ (how I learn from the action and understand its effectiveness). Steps within the AR process (e.g. identifying an issue, planning, acting, reflecting on the action and then acting again in new ways in light of what is found) invariably recur in a cyclical process throughout the study in a similar sequence and with critical reflection upon the process and outcomes. They are important parts of each cycle. Therefore AR can be identified as a research methodology which is practice based and about improving practice (of both action and research).

4.2 Why did I choose an AR approach for this research study?

I needed an appropriate research methodology that would work for my research study, as Altrichter and Posch (1989, p. 29) suggested, ‘what’s good for the practice is good for research’. This research study is initiated aiming to improve the education system for maritime design students suffering from a lack of maritime HCD knowledge and practice. It was clear to me therefore that in order to achieve the aims of this research study, it would be vital for there to be purposeful actions or activities to motivate, facilitate and encourage guide maritime design undergraduates to learn, understand and apply an HCD approach within the design activities of their studies.

I also understood the need to develop an understanding of the effectiveness of the actions I was going to take. It was thus a process of investigating how the actions would contribute to the improvement of student understanding of maritime HF and HCD, and that could further help me to modify the action plan in the light of what was discovered, and continue on with it. In this way I realised that the reflections of actions and their outcomes were important parts of this research study.

According to understanding developed through literature, AR is a methodological framework that will enable my research to accomplish its research aims. It was clear to me that AR could provide functionality to the pedagogical framework constructed. It also could help to evaluate the effect of the teaching framework and HCD knowledge dissemination activities within this study to assist in accomplishing the research aims. AR as a methodological framework could also provide me with the opportunity for self-development as a researcher while improving student levels of HCD understanding. Considering all these facts, I came to understand that AR could provide the methodological framework for this research study.

Harland (2003) successfully used AR methodology to study the effectiveness of a Zoology teaching program which was developed by connecting PBL and Vygotsky’s ZPD theory and scaffolding concept. The author documented a reflexive critique of experiences over three action cycles, and identified areas of practice influenced by ZPD theory. Although much of Vygotsky’s original work was done in the context of the language learning of children (Vygotsky, 1962), Harland was able to broaden it to university education, due to its logical approach to accessing student layers of development through effective learning methods.

Balakrishnan (2009) explored new ways of teaching Moral Education in Malaysia using Vygotsky's ZPD theory through AR methodology. This was to involve students in active communication and discussion to resolve some of the real-life dilemmas that they were facing in their daily lives.

Furthermore he recognised AR as a form of research methodology that prioritises the effects of the researcher's direct actions of practice within a participatory community.

Chen et al. (2009) also used an AR method to evaluate the influence of Vygotsky's ZPD theory and scaffolding approach within PBL-driven unit for nursing education. They explored the usefulness of scaffolding nursing students within a PBL environment that involved diagnostic tutorials and engaged in reciprocal dialogue between the tutor and student, from the perspective of constructive learning. Similarly, Walker et al. (2001) conducted an AR study to evaluate a PBL-driven course in order to find out how its format developed student understanding and integration of knowledge.

Snyder and Wiles (2015) evaluated the potential effects of PLTL instructional model on a PBL-driven biology course through AR methodology. This investigation also evaluated the effect of PLTL approach on peer leader perceptions and their critical thinking skills. They state that the students who participated in PLTL sessions attained significantly higher exam marks and final course grades than those who did not. Despite these few studies however, a literature search reveals that little or no research has been done specially in engineering education to study the influence of Vygotsky's ZPD theory and scaffolding approach within a study unit which is developed by connecting PBL and PLTL pedagogies. An application of this kind of research however is essential.

4.3 Which tradition of action research is followed in this research study?

Researchers who use AR as a methodological framework will be steeped in a particular tradition. Nevertheless, according to Herr et al. (2005, p. 9), 'in many cases, the issue is not that one or another tradition is better, but that it may be more or less appropriate to the particular study'. For that reason I also needed to find a research tradition which would be congruent and suitable for this study.

Is Action Science appropriate for this study? Action science is mainly associated with the work of Argyris et al. (1985), whose principal concern was organisational development and organisational learning. This tradition uses as a framework for learning how to be more effective in groups and to study how human beings design their actions in difficult situations. Hence the goal of action science was to reduce individual and group ineffectiveness caused by defensive interpersonal and organisations relations, and to improve problem solving skills as well as the confidence of individuals in organisations. This has helped individuals, groups, and organisations to develop a readiness and ability to learn how to overcome barriers within organisations which often have an ever changing environment (Argyris, 1983, 1990, 1999; Argyris & Schon, 1974; Argyris & Schön, 1978). As my research goal was not similar to the goals of action science (which is organisational development and organisational learning), it became clear that the Action Science tradition was not appropriate for this research study.

Is Action Learning appropriate for this study? Revans, who is acknowledged as the founder of action learning, developed the principles during the late-twentieth century (Revans, 1980). Action learning is a process that involves a small group called an action learning 'set' working on real problems, taking action, and learning as individuals, a team, and an organisation while conducting a study (Pedler, 2011; Revans, 1980, 1982). According to Pinchen and Passfield (1995), the focus of the action learning 'set' is to bring current work related issues or challenges to the group to be worked through in a reflective manner. This tradition has emerged as one of the most popular methodologies in business organisations so as to develop leaders and teams and enhance professional competencies, as well as to solve difficult problems (Clark, 1972; Pedler, 2011). This made it clear to me that the Action Learning tradition was not suitable for this research study since my research does not involve an action learning 'set'.

Is the educational tradition of AR methodology appropriate for this study? The educational nature of this research initially guided me to consider some educational traditions that already had integrated AR methodology within them. However, as explained below, several factors showed me that my research did not fit with them. Namely, there are several types of AR in the field of education depending upon the focus of the research. A plan of research can involve a single teacher investigating an issue in his or her classroom, which is known as individual teacher research. Alternatively, it may be a group of teachers working on a common problem, which is known as collaborative teacher research. It may also be a team of teachers and others focusing on a school-or district-wide issue which is known as school wide AR (Ary et al., 2013). Each of these will be considered below.

Individual teacher research usually focuses on changes in a single classroom. The teacher seeks solutions to problems of classroom management, instructional strategies, use of materials, or student learning. Many teachers practice personal reflection on teaching, others conduct formal empirical studies on teaching and learning (Mettetal, 2012). However, the ultimate goal of individual teacher research is to improve a teacher's own teaching in her/his own classroom and improve student learning (Dadds, 1995; Noffke, 1997; Stenhouse, 1975).

A team of two or more researchers including some teachers, the principal, university professors, and school board also often conduct collaborative teacher research in education. Depending on the numbers of teachers involved, collaborative teacher research can focus on problems and changes in a single classroom or on a problem occurring in several classrooms. Researchers might even take on a district wide problem, but focus their inquiry on one classroom. The members of the research team are the primary audience for results from collaborative teacher research in education. Depending on their involvement in formulating and shaping the investigation, students and parents may form part of the primary audience (Allen et al., 1988; Corey, 1953; Joyce, 1991; Strickland, 1988).

A school wide AR process involves the entire faculty in conjunction with a school consortium. This tradition may involve every faculty member of the school in the investigation of a specific issue. Firstly, the members of school faculties select an area or problem of collective interest. They then collect, organise, and interpret on-site data. Data from other schools, districts, or the professional literature are funnelled into the collective decision-making sections of the faculty, who then determine the actions to be taken (Calhoun, 1994). Successful school-wide AR is directly related to initiatives contained within a school's improvement plan (Allen & Calhoun, 1998; Clauset et al., 2008; Pine, 2008). It was clear to me that I am not going to be a classroom teacher/individual teacher or in teacher collaboration with other teachers, the principal, university professors or other universities in this particular study. Therefore, it was quite clear that the above traditions were not applicable to this research study.

Is Participatory Action Research appropriate for this study? Examination through the literature has showed me that there is no clear distinction between AR and participatory action research (PAR), and in fact the terms are at times used interchangeably. Reason (2001) described about AR, PAR, action learning, and action science, which are contemporary forms of action oriented research, and which place emphasis on a full integration of action and reflection so knowledge developed in the inquiry will be directly relevant to the issues being studied. Furthermore, as described by Koshy (2005), AR is also known as PAR, community-based study, action science and action learning, which is an approach commonly used for improving current practice in some communities, programs or organisations.

However, according to Kemmis et al. (2005), Denzin and Lincoln (2008), and Baum et al. (2006), PAR is a research process followed in settings such as those of education, community development, and cross-cultural contexts (McTaggart, 1991), when people individually or collectively try to understand how they can form and reform in a variety of settings. For example, teachers work together, or with students to improve processes of teaching and learning in the classroom. Greenwood et al. (1993) captured the essence of PAR by stating that it is a form of AR in which social researchers operate as full collaborators with members of organisations in studying and transforming those organisations. Hence, PAR can be viewed as a way of bringing full collaborative participation into the AR process (Elden & Levin, 1991).

Particularly difficult, according to Kindon et al. (2007) and Greenwood et al. (1993) is that the term ‘participation’ covers different levels of engagement within the PAR tradition. Participation may describe an active involvement of participants in all aspects of a PAR project, or it could be limited to particular stages and times. Who participates, how they participate, when they participate and why they participate are questions which expose real differences amongst researchers, and this is reflected in the diverse range that exists among PAR projects (Mackenzie et al., 2012). I therefore interpreted this to mean that AR can become PAR depending on who, how, when and why it is involved in stages of an AR project.

Biggs (1989) distinguished four modes of participation in research: ‘contractual,’ ‘consultative,’ ‘collaborative,’ and ‘collegiate,’ where control over the research process gradually shifts from researcher to participants or local people. Cornwall et al. (1995) elaborated on Biggs’ (1989) four modes of participation in their discussion on varying degrees of participation in participatory research approaches. Later, Cornwall (1996), provided a useful list of the varying degrees of participation/collaboration that take place in PAR as displayed in Table 4.1.

Co-option is the lowest level of participation, and as engagement in the process increases gradually participants begin enacting their own agenda in a collective action mode. Cornwall (1996) stated that it is possible to have several modes of participation running simultaneously, depending on the participants involved. For example, in Nicoll and Butler (1996)'s study, teachers and voluntary nursing students closely worked to bring about changes to the nursing curriculum relating to the study of biology, whereas others participated only when required. The overall responsibility of research design and decision-making remained with Nicoll and Butler, who were outside researchers. Overall, therefore, I realised that it would be unwise to suggest that there is a threshold level of participation that would guarantee success in a PAR project.

Table 4.1: Modes of participation in PAR.

Mode of Participation	Involvement of participants
Co-option	Participants are identified as representatives, they agree to provide a service, but there is no real input or power within the research process. Ex: Provide support for researchers in the field in the form of help with logistics, food, and shelter
Compliance	Tasks are assigned to participants, the researcher defines the tasks, and the researcher decides the agenda. Participants do not have real input or power within the research process
Consultation	The researcher defines all the key decisions during the research process, but emphasis is put on consultation and gathering information from participants, especially on identifying opportunities for improvements or change within the process. During consultation, participant options are sought. However, the researcher analyses and decides the appropriate development of the process.
Cooperation	Participants work together with the researcher in implementation. However, the research is initiated, designed and managed by the researcher. Responsibility remains with the researcher for directing the process.
Colearning	Participants and the researcher share their knowledge in order to create a new understanding, and they work together to form action plans with researcher facilitation.
Collective action	Participants have the power to make important decisions during the research process with an emphasis on mutuality in terms of planning, managing and designing of the research. Participants set their own agenda and mobilise to carry it out in the absence of the researcher.

The responsibility remains with me for directing the process of this research study, since I need to design and manage the whole research project. Participants will not be involved in initiating, planning, decision making, designing the overall study, or managing the process of data collection and the research process. Therefore the power and the responsibility will deliberately not be shared between the researcher and the participants in order to make collaborative decisions. However, as explained in Chapter 3, Section 3.5, HCD champions will collaboratively work with facilitators and their suggestions and feedback will influence improving the actions and modifying the initial action plan. Thus, HCD champions can be identified as implementers of the actions who will provide necessary data to the researcher to improve and modify the research plan. In this way, HCD champion participation can be identified as a cooperation mode of participation according to Cornwall (1996).

The design project team members will not be working as closely with the researcher in implementing actions as HCD champions will be. Thus, their interaction cannot be viewed as a cooperation mode of participation. However, their consultations at the end of the cycle will be vital to gather information for identifying the effectiveness of efforts taken to elevate HCD knowledge through the HCD champions, as well as in identifying opportunities to improve or change the scaffolding program and the pedagogical framework. Consequently, a consultative mode is recognised as the project teams' mode of participation.

In addition, HF specialists and field experts will not be involved in decision making or managing the workshops or activities, but rather, they will provide support to stimulate the students' HCD knowledge when needed and upon my invitation, as well as based on their availability. Hence, their participation during this study can be identified as a co-option mode of participation, where they agree to provide support during the research study.

Similarly, permission and support is needed from faculty members at AMC to conduct this study. They will not, however, be involved in decision making or managing the workshops or activities. Thus, faculty member support can also be identified as a co-option participation mode. Thus, I have come to recognise that my research study has shades of PAR within the AR research paradigm, with the flexibility of choosing several modes of participation.

4.4 Positionality of the researcher

Researchers under the AR paradigm take many different positions, from being an insider to being an outsider, based on the different settings of their studies (Herr et al., 2005). Insider researcher is where a person is carrying out a research study within his organisation or work setting. On the other hand, outsider researcher is recognised as being conducted by a non-member of the organisation. Traditionally action researchers have been seen as outsider change agents and it was assumed that that kind of research was to be initiated by an outside researcher (Herr et al., 2005; Mock, 1999). Nonetheless, Herr et al. (2005, p. 31) describe six positions along the insider-outsider positionality continuum and they are:

i. Insider studying own self or practices
ii. Insider in collaboration with other insiders
iii. Insider in collaboration with outsider(s)
iv. Reciprocal collaboration (insider-outsider teams)
v. Outsider(s) in collaboration with insiders(s)
vi. Outsider(s) studying insider(s)

Within the first positionality, insiders reflect on themselves or their positionality and they focus on their personal and professional self, which is a form of AR usually called self-study (Bullough & Pinnegar, 2001) or autoethnography (Bochner et al., 2002; Petersen, 2010; Reed-Danahay, 1997). Although studying one's own self or practices cannot be separated from the setting that the research takes place in, the researcher who falls into this position must focus on their own practices versus the actions initiated within the setting (Bochner et al., 2002). Schön (1983) used the notion of the reflective practitioner to describe this positionality, where researchers learn to learn about their own practices so as to become better practitioners or researchers. Such studies can greatly benefit the professional development of the researcher while providing data on how they learn and grow in different professional contexts. When it comes to the second positionality the insider researcher works together with other insiders to achieve negotiated goals assuming that all participants are on an equal footing (Headman, 1992; Herr et al., 2005).

In the third positionality, organisational or community members contact or invite outsiders to collaborate on research. This can be a group of individuals coming together to address common concerns with the support of an external agent. In the fourth positionality, partnerships are formed between action researchers, sometimes working in groups between different contexts. Bartunek and Louis (1996) used the term insider-outsider team research for these kinds of studies carried out by true collaborations among participant researchers. This true collaboration means that the insider and outsider researchers jointly initiate and implement the research study by developing insider-outsider teams.

The fifth positionality is of outsiders in collaboration with insiders, and is the most common positionality in PAR traditions (Herr et al., 2005). In this, outside researchers enter into the research context with the mindset shown in the third quadrant of the four squares of knowledge (see Figure 4.1), published in Luft (1963). This often causes insiders to place themselves in the second quadrant, undervaluing their knowledge. However, the goal of this type of collaboration is to reduce the tendencies of the second and third quadrants, and to expand the tendency of quadrant 1.

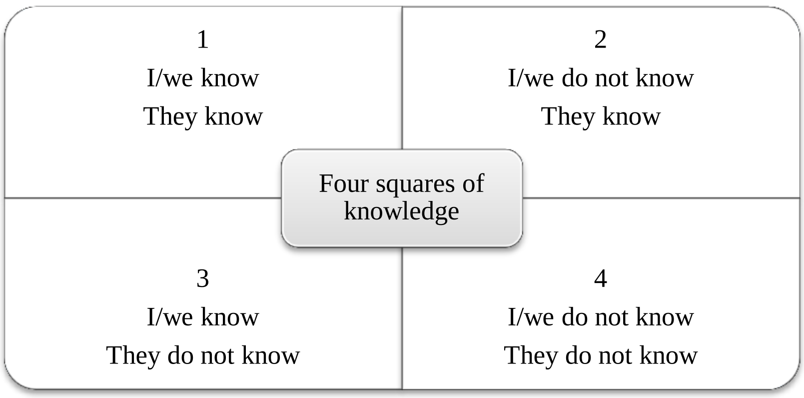


Figure 4.1: Four squares of knowledge (Luft, 1963).

The last positionality, which is outsider studies insider, describes the traditional outsider position taken by quantitative or qualitative researchers. For example, O'Donnell-Allen (1999) did a study on a teacher research group, but positioned herself as an outsider. She makes no pretence of doing collaborative research of any kind. Her goal was to consult and gather information from her participant teacher group to collect examples of teacher discourse.

Researcher positionality however does always not fall into a neat category and might even shift during a study (Herr et al., 2005), much in the same way as the positionality of participants described by Cornwall et al. (1995). For example, Spjelkavik (1999), in her study of Norwegian fish farms, began as an outsider doing applied research aimed at generating knowledge of rural development and survival strategies in marginal or remote areas. She positioned herself as an outsider studying an insider position at the beginning. The study evolved however into PAR as the relationships with informants deepened, which changed her positionality to an outsider in collaboration with insiders.

As explained in the previous section of this chapter, although HCD champions work closely with the researcher in implementing actions, they are not involved in initiating, planning, decision making, and designing of the overall study, or managing the process of data collection and the research process. Therefore, I do not recognise the collaboration with HCD champions as being reciprocal. Subsequently, the collaboration I have with the HCD champions in my study is not a full partnership, but it is similar to the collaboration described in the fifth positionality, which is of an outsider in collaboration with insiders. This is in the third quadrant of the four squares of knowledge (Luft, 1963), when in a research context. HCD champions are in the second quadrant since they want to improve their HCD knowledge. The ultimate aim would be to reduce the strength of second and third quadrants while increasing the strength of the first quadrant during collaborative research study. Subsequently, I realised that ‘outsider in collaboration with insiders’ is my positionality in relation to HCD champions.

With respect to design project team members, they are not closely working with me during the research implementation with HCD champions, so I do not recognise that collaboration as either reciprocal or as an outsider in collaboration with insiders. However, I need to consult them at the end of the cycle to gather information and identify the effectiveness of the effort taken to elevate their HCD knowledge through the HCD champion concept, and to identify opportunities for improving and changing the scaffolding program and framework developed for the study. Thus, I realised that ‘outsider studying insiders’ is my positionality in relation to design project team members.

In relation to the faculty members at AMC, my position can be seen as that of an outsider. It is possible however to consider myself as a part of the AMC institution as an insider, since I am doing this doctoral research under the auspices of AMC. However, I came to realise that my position was as an outsider to the particular faculty members at AMC, since I stand always outside in relation to their professional setting as teachers.

4.5 Data collection methods

Elliot (1991) lists qualitative and quantitative methods of data collection such as document review, journal keeping, photographic evidence, tape or video recording, using outside observers, interviewing, checklists, questionnaires, inventories, as well as profile review, which are all evaluation techniques within the AR process. According to Moon (2004), the enquiry-reflection process at the heart of learning in AR is enabled by journal keeping. Hopkins (1985) adds field notes, sociometric analysis, documentary evidence (like memos, letters, papers, reports), case studies, and shadowing (Sagor, 1993). Furthermore, Kemmis et al. (1988) also lists anecdotal records, ecological behavioural descriptions, logs, and portfolios. Some of these data collection methods are briefly summarised below.

A research journal keeps a systematic, and regularly kept record of events, dates and people, and is a record of the researcher’s interpretative, self-reflective personal experiences, thoughts and feelings as a means of helping them understand their own actions. Research journals are analytical tools where the data can be examined and analysed, and through the research journal materials the researcher can find evidence for the influences of actions taken by themselves (Maykut & Morehouse, 1994; McKernan & McKernan, 2013; Moon, 2004).

Interviews are an important part of any AR project as they provide the opportunity for the researcher to investigate further, to solve problems and to gather data which could not have been obtained in other ways. Interviewing is useful when there is a need to focus on a specific aspect of research in detail, to improve it, or when researcher-participant discussions can better provide general investigative information (Brinkman & Kvale, 2015; Kvale, 1997). Interviewing is a good way to find out what a situation looks like from other interacting participants’ point of view (Elliot, 1991; Kvale, 1997). According to Hopkins (1985), interviewing can take four forms based on between whom it occurs: researcher-participant, outside observer-participant, participant-participant, or occasionally researcher-outside observer. Interviews can be structured, semi-structured, or unstructured (Elliot, 1991).

In structured interviews, the interviewer determines the questions. Typically the aim of this approach is to ensure that each interviewee is presented with exactly the same questions in the same order, usually based on a questionnaire (Mitchell & Jolley, 2009). This enables answers to be reliably aggregated and comparisons made with confidence between sample sub-groups or between different survey periods. In semi-structured interviews there are typically some predetermined questions to discuss, but the form and order of the questions is free. Semi-structured interviews allow flexibility, since the questions follow the flow of the informant rather than being asked in the order of the guide, so it is important that the interviewer is flexible and sensitive to the informant. By using semi-structured interviews, it is feasible to compare the answers from several interviews and, to a certain extent, to make some generalisations (Berg, 2004).

In unstructured interviews the initiative for raising relevant topics and issues is left to the interviewee. The interviewer merely sets the theme or topic, and possibly asks the interviewee to expand, explain or clarify some points (Elliot, 1991; Hopkins, 1985; Kvale, 1997; Mitchell et al., 2009). Interviewing as a data collection tool has major advantages, such as: the interviewer is in direct contact with the participants, the interviewer can gain a deeper understanding of the validity of responses, the interviewer is able to seek the desired information directly, and better explanations are possible as the interviewer is able to develop a rapport with respondents. The disadvantages of interviewing are the time demands on the researcher and the difficulties faced in getting participants to explain their thoughts and feelings (Berg, 2004; Lapan et al., 2011).

Questionnaires are a good way to elicit other people’s observations and interpretations of situations and events (Elliot, 1991; Lapan et al., 2011). They are a quick and simple way to obtain wide-ranging and rich information from participants. Typical questionnaire forms are postal or internet forms, and controlled questionnaires. Postal or internet questionnaires are mailed to participants and controlled questionnaires are either delivered personally in research situations, or gathered personally after a stated period of time. Typically questionnaires contain open, multiple-choice, or scaled questions. The main advantages of questionnaires in use are the ease of administration they offer – quick to fill in and easy to follow up. They provide the ability for a direct comparison of group and individual answers, provide feedback from different points of view, and the data is quantifiable (Hopkins, 1985). Questionnaires have disadvantages as well, such as difficulty in getting answers returned, difficulty in creating questions that explore the issues in depth, a fundamental dependence for effectiveness on the reading ability and comprehension of respondents, a possible reluctance in respondents to answer candidly and their attempts to produce the ‘right’ answers (Berg, 2004; Patten, 2001).

Documentary evidence is another method for collecting rich data. Hopkins (1985) defines memos, letters, examination papers, project reports, and newspaper clippings as documentary evidence. Furthermore, Elliot (1991) has added into documentary evidence such things as curriculum reports, minutes of meetings, work cards, sections from student textbooks, student assignment sheets, and samples of research participant’s written work. According to Hopkins (1985) these documents provide rich data, but the researcher may face issues such as difficulties obtaining the documents, unwillingness among the participants to share confidential records, and an extended amount of time needed to obtain the written materials.

Case studies are utilised as a method of data collection in order to gain an in-depth contextualised examination of social interactions within a single social setting; this may be within an organisation or focused on the playing-out of a specific social process. The case study method itself includes several data collection methods such as interviews, observations, questionnaires, and documentary analysis (Berg, 2004). Checklists are structured observation tools used when specific, predictable results are expected. They can be simple lists of criteria that can be marked as present or absent, or can provide space for observer comments. These tools can provide consistency over time or between observers (Elliot, 1991).

For this research study I need to find evidence for the effectiveness of the constructed pedagogical framework and the HCD knowledge dissemination activities delivered through the framework. This is so that I can reflect on outcomes for further improvement and validation. In order to do that I have accommodated a number of data collection methods. For the entire period of this research study, I maintained a research journal. I attempted to keep it updated on a daily or weekly basis depending on the research process. It was filled with notes taken down during every action within the research process. Furthermore, I always used other resources such as photos taken during the research process, presentations prepared during it, in-and outgoing emails, and other available representations to keep my memory on track. Such materials indeed helped me to update my research journal.

I also used my research journal to make reflections throughout the process of the research study and to find evidence of the effectiveness of the efforts taken, especially throughout the action implementation phase. Furthermore, in order to make the representation transparent and to help the readers follow in my footsteps (Schön, 1983), I used quotes (from students and myself) from my research diary as widely as possible throughout my reflections and results (see Chapter 5 and 6). I also did not forget to discuss the summary of my research journal with my research primary supervisor and one of the co-supervisors, who both have experience in AR projects. They reviewed my reflections, opinions and interpretations on the collaborative process with HCD champions.

Furthermore, I wanted to find out how the HCD knowledge dissemination activities elevated the HCD understanding of HCD champions. I also desired to collect feedback and suggestions from HCD champions on the activities of HCD knowledge dissemination and their delivery methods. I wanted to hear from them about their experience as HCD champions within their teams. In order to do this I conducted individual semi-structured interviews with HCD champions after the scaffolding program. The predetermined questions included were reviewed in beforehand by the research supervisor and two of my professional colleagues. The questions were revised based on their comments before I conducted the interviews.

Additionally, I wanted to find out the effectiveness of HCD champions' guidance and facilitation to elevate the HCD understanding of their team members within the study. For that reason I needed to evaluate the HCD understanding of team members. Not only that, I had to search out their opinions on HCD champion facilitation and guidance as a peer leader in a team and get their feedback and suggestions on HCD knowledge dissemination activities. In order to do this I used an internet questionnaire as a data collection method. The use of interviewing was not originally promising due to the time demands and difficulties in getting all team members together. In order to expose any difficulties with questionnaire completion and increase data accuracy, I conducted a pilot study with my professional colleagues. Comments provided by them identified several aspects that needed to be changed to increase comprehension and specificity, and I corrected these before distribution.

In addition I needed to search for evidence of team application of the HCD approach in their design projects. As the fourth data collection method, I used the method called documentary evidence. In summary I accommodated the following data collection techniques to evaluate the effectiveness of the pedagogical framework and the HCD knowledge dissemination activities:

- Researcher's journal
- Interviewing of HCD champions
- Distributing of an internet questionnaire to team members
- Documentary evidence - reviewing design project reports

In addition, at the commencement of this AR study, to evaluate student awareness and understanding of maritime HF and HCD, a questionnaire was distributed to students in the classroom. Furthermore, a few concept design reports of two previous undergraduate groups at the AMC were reviewed in order to find out the baseline application of the HCD approach in their design projects.

4.6 Data analysis methods

AR data can be analysed using qualitative and quantitative data analysis methods. Qualitative methods generate volumes of descriptive data, and analysis involves looking at that data, describing or summarising it clearly, searching for consistent categories or themes in it, and linking and connecting those categories with each other to look for meaning and causes (Elliot, 1991; Kemmis et al., 1987; McNiff et al., 2003). In other words, analysis can be done either by content (Philipp, 2000) or by theme (Marshall & Rossman, 1995). According to these authors, the researcher has to follow the following key stages while analysing qualitative data within a context of AR:

- Detailed description of the data - In order to become acquainted with the data, tape recordings have to be listened to several times, and transcripts and notes have to be read and re-read while impressions and thoughts are being recorded
- Systematisation and categorisation of the data - This can be organised around the questions or aims of the studies, in order to identify consistencies and differences in the material, and to look for any emerging themes, patterns, interactions or terminology that recur in the data. The data can be organised into summarising categories in an iterative process, labelling and re-labelling the categories until no new themes can be identified
- Linking and connecting of data to find meanings and causes. Here, the data is interpreted, looking for relationships and meanings within it

In this study, I have used content analysis to examine the qualitative data that I collected throughout. Content analysis refers to a family of procedures for the systematic, replicable analysis of written texts (speeches, letters, articles, video, films, or other visual communication messages). In essence it involves the classification of parts of a text through the application of a structured, systematic coding scheme from which conclusions can be drawn about message content. Therefore, through content analysis, it is possible to distil multiple words into fewer content-related categories (Cole, 1988; Downe‐Wamboldt, 1992; Harwood & Garry, 2003; Krippendorff, 2004).

Content analysis can be carried out in an inductive or deductive way based on the purpose of the study. Within the inductive approach, categories are derived from the data through the researcher's careful examination and constant comparison. Deductive analysis is used when the structure of analysis is operationalised on the basis of previous knowledge of some empirical research and the purpose of the study is the testing of a theory (Elo & Kyngäs, 2008; Zhang & Wildemuth, 2009). An approach based on inductive data will move from the specific to the general, so that particular instances can be observed and then combined into a larger whole or a general statement. A deductive approach will be based on an earlier theory or model, and therefore it will move from general to the specific (Krippendorff, 2004). Since the purpose of this study was not the testing of a theory of a previous empirical study, the structure of the analysis was not operationalised on the basis of previous knowledge. Instead, I have used an inductive content analysis approach.

Content analysis has three main phases: preparation, organisation and reporting (Elo et al., 2008; Philipp, 2000; Zhang et al., 2009). There are no systematic rules for analysing data; the key feature of all content analysis is that the many words of the text are classified into smaller content categories (Weber, 1990). During the preparation phase, the data needs to be transformed into written text if it was recorded. If the data came from existing texts, the choice of the content must be justified by what the researcher wants to know (Patton, 1990). According to Zhang et al. (2009) and Schilling (2006), when transcribing data, the following questions may arise: (1) should all the questions, or only the main questions of the interview guide be transcribed; (2) should the verbalisations be transcribed literally or only in summary; and (3) should observations during the interview (e.g., sounds, pauses, and other audible behaviours) be transcribed or not?. A verbatim transcript may be the most useful, but the additional value it provides may not justify the additional time required to create it (Elo et al., 2008). The researcher also has to select the unit of analysis, which is the major entity being analysed in the study; it is the 'what' or 'who' that is being studied. The unit of analysis could be an individual student, a group, or even an entire program (De Wever et al., 2006; Weber, 1990).

Within the organisation phase, the process includes open coding, creating categories and abstraction. Open coding means that notes and headings are written in the text while reading it. In other words, making brief notes in the margin when interesting or relevant information is found (Neuendorf, 2002). The reading and re-reading of the transcribed data as many times as possible is paramount in order to highlight as many headings and notes as necessary, which strengthens the open coding to describe all aspects of the content (Harwood et al., 2003; Philipp, 2000). Once this coding is completed, the reading and re-reading of the heading and notes written down can help extract several emergent categories/themes. These main categories can be analysed critically even further to identify sub-categories (Krippendorff, 2004; Lapan et al., 2011). When formulating categories by inductive content analysis, the researcher comes to a decision, through interpretation, as to which things to put in the same category. Furthermore the researcher can identify whether or not the categories can be linked in any way, and then list them as major or minor categories (Dey, 2003). The next step then involves making sense of the themes or categories identified. At this stage the researcher will start drawing conclusions from the data. This is a very critical step in the data analysis process.

In the result sections of Chapter 5, I explain the major categories that I found during the analysis of interview and questionnaire data, how those categories made sense, and how I made interpretations and conclusions based on them. Also, I read and re-read my research journal in order to become familiar with the data, and use it to develop reflections on the actions, as well as to compile what I had learnt during action cycle. I used my research journal to find evidence of the effectiveness of the effort taken, especially throughout the action implementation phase. In addition to content analysis, I used a single marking descriptor/rubric (see Table 4.2) to assess the HCD understanding of HCD champions and team members. In addition, I used another marking descriptor/rubric (see Table 4.3) to review the design project reports.

According to Airasian and Russell (2008), rubrics provide a systematic methodology for judging the quality of student work, based on criteria for different performance measurements. A rubric is described in the educational literature as a 'simple assessment tool that describes levels of performance on a particular task and is used to assess outcomes in a variety of performance-based contexts' (Jonsson & Svingby, 2007, p. 131). This assessment tool is used across many disciplines to assess student reports and papers (Kellogg et al., 2001; Moskal, 2000), student team skills (Plumb & Sobek, 2007), oral presentations (Jones & Tadros, 2010; Moskal, 2000), as well as large-scale student projects (Bailey et al., 2004; Chong & Romkey, 2012; Jones et al., 2010; Watson et al., 2013).

Airasian et al. (2008) differentiate between holistic and analytic rubrics: holistic rubrics provide single descriptions for each performance level (e.g., standard) while an analytic rubric is more granular, and it provides descriptions for each performance criterion. Furthermore, holistic rubrics are single criteria rubrics (one-dimensional) used to assess the overall achievement of a participant on an activity or item based on predefined achievement levels (Moskal, 2000). Performance descriptions are written in paragraphs and usually in full sentences. Analytic rubrics are two-dimensional rubrics with levels of achievement as columns and assessment criteria as rows. This allows the evaluator to assess participant achievements based on multiple criteria using a single rubric. An assessor can assign different weights (values) to different criteria and include an overall achievement by summing up the criteria (Bailey et al., 2004). During this analysis, since I wanted support from the rubric to achieve a broader judgement about the HCD understanding of HCD champions and team members as well as the level of HCD integration into the design project, I decided to use a holistic single criteria rubric.

I utilised a holistic single criteria rubric developed by Emelina (2014) to make broad, holistic judgments about how senior students in an aircraft design course understood the HCD approach and the quality of stakeholder consideration within their design process. She developed a 'design understanding scale' to find out whether the students were linear designers or reflective designers. This scale encompassed five levels, from 'lacks a basic understanding of the HCD approach' to a 'deep understanding of the HCD approach'. Her second scale to judge integration of stakeholder requirements into the design process was a 'stakeholder integration scale'. This scale also included five levels, from 'lacks integration' to 'excellent integration'. She further examined the validity, clarity, and reliability of these rubrics with a group of seven subject matter experts (Emelina, 2014).

I decided to employ these holistic rubrics, with minor modifications to wordings in order to represent the maritime engineering domain. The modified analytic rubrics for this research study are in two parts. The first is called 'the HCD understanding scale' in order to assess the understanding of HCD champions and team members concerning a HCD approach in maritime design as delivered within scaffolding sessions. The HCD understanding scale encompasses five levels and descriptors for each level, which are shown in Table 4.2. The second rubric, which is 'the HCD integration scale', is focused on assessing the application of a HCD approach during the design process. The HCD integration scale encompasses five levels and had descriptors for each level, which are shown in Table 4.3.

Table 4.2: Rubric-A; The HCD understanding scale.

Level	HCD understanding	Description
0	Lacks understanding	Does not explain HCD at all or attempts to explain HCD, but the explanation shows an incorrect understanding of it (e.g., HCD is common sense). (i.e. Does not demonstrate theoretical knowledge of HCD or an understanding of HCD application)
1	Basic understanding	Identifies HCD as a design approach, which focuses on making systems usable by applying HF and Ergonomics knowledge during the design process, and defines it correctly. (i.e. Demonstrates a very basic theoretical knowledge but no understanding of HCD application)
2	Moderate understanding	Identifies HCD as a design approach, which focuses on making systems usable by applying HF and Ergonomics knowledge during the design process and defines it correctly. Further discusses the process, benefits and importance of HCD as presented within scaffolding sessions. (i.e. Demonstrates good theoretical knowledge, but no understanding of HCD application)
3	Sound Understanding	Identifies HCD as a design approach, which focuses on making systems usable by applying HF and Ergonomics knowledge during the design process, and defines it correctly. Discusses the process, benefits and importance of HCD. Abstracts the use of the principles of the HCD process to develop a user centred design through an iterative process. (i.e. Demonstrates good theoretical knowledge and understanding of the HCD application as presented within scaffolding sessions)
4	Excellent understanding	Exhibits excellent understanding of the HCD process. Demonstrates leverage of the perspectives of users to reach an innovative design that can be marketed as a user centred design. Notes any challenges in the HCD process and discusses the impacts of those on the final design. Displays well established understanding beyond that offered within scaffolding sessions. (i.e. Demonstrates good theoretical knowledge and good understanding of HCD application including challenges, limitations, and suggestions)

Table 4.3: Rubric-B; The HCD integration into design project scale.

Level	HCD integration	Description
0	Lacks integration	Lacks appreciation for end-users. Lacks a basic identification of users (e.g., primary and secondary), tasks and operational environment, as exhibited by missed steps or an incorrect application of HCD knowledge to the design task. Lacks end-user-based evaluation to ensure the design meets the needs of the users discussed during scaffolding sessions.
1	Elementary integration	Includes a few primary users and their key task-related considerations, but does not explicitly discuss the operational environment. Exhibits an effort to incorporate user needs at isolated points in the design process, but overall user requirements are not the basis for design decisions and not addressed consistently throughout the concept design. Design decisions lack end-user-based evaluation.
2	Developing integration	Identifies a few primary users and their key task-related considerations and demonstrates an effort to discuss the operational environment. Exhibits a marginal effort to incorporate user needs into the design process and in producing design decisions. Design decisions lack end-user-based evaluation to ensure design meets the needs of users discussed during scaffolding sessions.
3	Adequate integration	Exhibits a commitment to incorporating primary users, their key task-related considerations and operational scenarios as a basis for design decisions. Shows effort taken to link users and tasks and their frequencies to design layouts. Demonstrates the use of feedback from end-users and the pursuit of more user-friendly design via an iterative process, while justifying trade-offs between user requirements and design solutions. May utilise the use of HF guidelines as a best practice to develop their final design. May utilise additional analysis methods to re-evaluate the design as introduced during scaffolding sessions.
4	Excellent integration	Exhibits excellent commitment to incorporating all primary users, secondary users and their tasks, as well as their different operational conditions throughout the iterative design process. Demonstrates how multiple perspectives were integrated to develop their final design. Design shows a multiple iterative and reflective process based on frequent user feedback and ergonomic tool re-evaluations. Demonstrates concrete justification of the trade-offs between the user requirements and design solutions, as well as the use of HF guidelines as a best practice to develop their final design.

4.7 Quality indicators of AR

Validity in research refers to the degree of credibility that a piece of research has (Gall et al., 2003). Several questions come to mind when addressing this issue including: Are the conclusions from the data analysis accurate? Can this research be trusted as a reliable source? Does the researcher address bias in order to maximise the validity of the study? (Newton & Burgess, 2008). According to Herr et al. (2005), to reduce bias, the action researcher must declare his or her beliefs, values and experiences and these should become part of the research cycle of thinking, planning and acting, which the researcher constantly articulates and records in journal entries, field notes and also in the final reporting of the study. Action researchers thus do not depend on quantitative methodologies such as controlled experiments with independent and dependent variables, random sampling or laboratory settings to attain reliability, or to determine the degree to which the results of the study can be generalised. Rather they utilise thick description (Geertz, 1983), where they paint a picture of the phenomena being studied, so those who follow the research can evaluate it and see how closely it resembles (Stake, 1995). Herr et al. (2005) suggested five quality indicators for AR:

- Outcome validity: the extent to which outcomes of the research match the intended purposes of the research
- Process validity: the extent to which problems are framed and solved in a way that enables ongoing learning
- Democratic validity: the extent to which research is done in collaboration with all parties who have a stake in the problem under investigation
- Catalytic validity: the ability of the research process to transform the participants, deepen the understanding of the participants, and motivate participants to further social action.
- Dialogic validity: peer review process

<u>Outcome validity</u>

Greenwood and Levin (1998) call this criteria 'workability' and Jacobson (1998) uses the term integrity to discuss his criteria for good action research. Integrity must rest on 'the quality of action which emerges from it, and the quality of data on which the action is based' (Jacobson, 1998, p. 130). Thus, outcome validity is synonymous with a 'successful' outcome of the research project. Consequently, according to Herr et al. (2005) and Hendricks (2006), a researcher can measure outcome validity by asking if the initial problem of the research was solved; Did the AR project reach its desired goal? or Did the resulting action resolve the problem that led to the study?

<u>Process validity</u>

Process validity refers to the extent to which the chosen research strategies match the research tasks. Simply stated, do the research methodology and research tools within it measure the intended information? Are the findings the result of a series of collaborative and reflective cycles? It also refers to the extent to which a researcher frames questions so that continuous enquiry is permitted. The researcher who establishes this validity will also pay attention to utilising a variety of tools, for example, observation and interviews, so that one is not limited to only one kind of data source. Furthermore the researcher may revise these research tools as necessary (Herr et al., 2005). AR however, because it is a cyclical process of planning, acting, reflecting, and leading, lends itself to utilising process validity (Herr et al., 2005).

<u>Democratic validity</u>

According to Herr et al. (2005), democratic validity refers to the extent to which research is done in collaboration with all the parties who have a stake in the problem under investigation – and, if the research is not undertaken collaboratively, how multiple perspectives and material interests are taken into account in the study.

> 'For example, teachers, administrators, and counsellors may collaborate in doing AR to solve school problems such as student attendance or attainment. Are students seen as part of the collaboration in order to take multiple perspectives into the study?' (Herr et al., 2005, p. 56)

AR lends itself to utilising democratic validity because it is characterised as a participative process, and due to its action and reflection nature. The researcher establishes democratic validity when he/she establishes ethical procedures to ensure that the voices of participants are included and accurately represented in the research. Gall et al. (2003) maintain that informing participants of research goals and processes is one way to foster democratic validity. According to Herr et al. (2005), democratic validity is also attained by maintaining a relationship with the participants well after the research study has ended.

Catalytic validity

Catalytic validity is 'the degree to which the research process reorients, focuses, and energises participants toward knowing reality in order to transform it' (Lather, 1986, p. 272). In the case of action research, not only the participants, but the researchers/practitioners themselves must be open to reorienting their view of reality as well as their view of their role. According to Herr et al. (2005, pp. 56-57), 'the most powerful action research studies are those in which the researchers recount a spiralling change in their own and their participants' understandings. This reinforces the importance of keeping a research journal in which action researchers can monitor their own change process and consequent changes in the dynamics of the setting'.

Dialogic validity

Dialogic validity is essentially a process of peer review of the data and findings to ensure the efficacy of the researcher's claims (Gall et al., 2003; Herr et al., 2005). Not only Herr et al. (2005) but Martin (1987) also states that AR reports must pass through the process of peer review in order to be disseminated in academic journals, and they suggest that action researchers participate in critical and reflective dialogue with other action researchers in order to accomplish dialogic validity. According to them, working with a critical friend who is familiar with the setting can serve as a devil's advocate for alternative explanations of research information. Furthermore Herr et al. (2005) suggests that action researchers can promote dialogic validity by treating the research as a collaborative inquiry. I will demonstrate in Chapter 7 how I have employed these quality criteria within this research study.

4.8 Ethical framework of the study

Ethics involves authentic relationships between the researcher and the participants in the research, including between individuals, groups, organisations and communities (Rowan, 2000). Therefore, research study should as far as possible, be based on the participants freely volunteering informed consent. This implies a responsibility to explain fully and meaningfully what the research is about and how it will be carried out. Participants should be aware of their right to deny or discontinue participation; understand the extent to which confidentiality will be maintained; be aware of the potential uses of the data and results for producing publications; and in some cases be reminded of their right to re-negotiate consent (Rowan, 2000; Walker & Haslett, 2002).

At various stages of this study, I attained approval from the Human Research Ethics Committee (HREC) of Tasmania to conduct the study. The HREC of Tasmania reviews all research conducted with or about humans, their data or tissue, within the state of Tasmania, in accordance with the requirements of the National Statement on Ethical Conduct in Human Research. A detailed explanation of the study was provided to the ethics committee, including a justification for the choice of participants, how participants would be recruited, identifiability of the data, extent to which confidentiality will be maintained, procedure of the study including the methodological approach, the methods of collecting and analysis of data, how the researcher would store the data securely, and the procedure used to obtain consent from participants. The ethics approval letters related to this research were signed by the chairperson of the HREC committee and are attached in Appendix A.

I showed approval letters to faculty members, HCD champions and their team members at the commencement of the study as well as before each data collection activity in order to obtain their consent. Furthermore, I did not forget to explain fully and meaningfully what the research is about and how it would be carried out, to the faculty members, volunteered HCD champions and their team members. I also explained how I am going to publish the results of this research study by showing them the rough publication plan and reminding them of their right to re-negotiate consent. Furthermore, I made them aware of their right to refuse to participate. Throughout the research study, I kept good faith with my participants by showing them that I am someone who can be trusted and I always checked with them for any misunderstanding. Similarly, I maintained good trust with HF specialist and field experts who agreed to provide their support during the research. I also showed them the ethics approval letters whenever I attained their support and services during the study.

Chapter 5

Action cycle 1

This chapter presents the detailed description of action cycle 1, which comprises of planning the action, implementing the action and collecting data, analysing data and results, and discussion and reflection. The reflections are included within the chapter explaining the success or failure of the actions in order to improve the HCD knowledge dissemination program within the next cycle of this research study. The chapter begins with how the researcher entered into the research context and the initial fact-finding includes evaluating the HF and HCD awareness of the selected cohort of students.

5.1 Entry in to the research context

According to Herr et al. (2005), Action research dissertations should make clear how the researcher negotiated to enter into the research context. During several discussion sessions I had with faculty members – the design project unit coordinator and the lecturer – I explained the overview of the research study including the problem outlined, the aim and the objectives. To explain HF issues within ship designs, I used real-world published examples and many examples from the ship design experience I have as a naval architect. I showed pictures and videos of those examples. Furthermore, I explained why I selected the design project unit for this study. In addition, the pedagogical framework and its operationalisation were explained to the faculty members. The data collection activities to be employed within the study and the ethical framework of the study were also explained to them.

The faculty members recognised the significance of this study. They also confirmed the nonexistence of the HF and HCD related subjects within AMC's maritime design undergraduate degrees. In addition, they were not aware of any other marine engineering degree courses that included HF and HCD units. By looking at the teaching framework, they identified the capabilities of a PBL-driven design projects to integrate maritime HCD knowledge into design education. They acknowledged the approach I intended to employ in order to maintain the authentic relationship between participants and the researcher. Ultimately, the faculty members gave permission to conduct the research study with final year maritime design undergraduates who enrolled in the design project unit. They also granted permission to conduct data collection activities. Not only that, they agreed to provide their support throughout the research study.

<u>Reflections:</u>

Reflecting on the discussions I had with the faculty members, I was overjoyed to receive their support and permission to initiate this study. However, in the beginning I took this as an immense challenge since I was new to the AMC and would be the first PhD researcher who was doing non-technical research with technical people. The challenge was how to convince faculty members of the importance of non-technical topics such as HF and HCD for engineering students. Therefore, I prepared thoroughly with real-world examples of HF issues within ship designs. Furthermore, since I have ship design experience, they were happy to listen to my experience with evidence to show the real-world HF issues within ship designs. In addition, I felt that if I was not a naval architect it could have been a difficult task to convince them and enlist direct and genuine support to implement such research within technical undergraduate study programs. I realised that as an outsider researcher it is advantageous to have strong negotiation skills and a technical background, with an appreciation of the importance of non-technical skills, to achieve a positive outcome in this kind of entrance discussion. Furthermore, I understood that it could have been easier if one of the faculty members played the researcher's role in this kind of study, since teacher researchers are themselves actors in the context they explore (Check & Schutt, 2011). As insiders, they are typically a part of the university setting and in charge of the classroom they are researching and thus the entry process, an initial hurdle for outside researchers, would be fairly easy for them (Ary et al., 2013; Hopkins, 1985).

The points I revealed during the entry process discussions will be vital to future researchers who are going to follow in the footsteps of this research, especially those with a non-technical background. The first point is to be cautious when speaking to an engineer about non-technical topics, as the engineers always give answers appropriate to the resources that can be dedicated to the issue (Koen, 1985, p. 53). Secondly, it is very important to prepare answers to the questions, 'Why is the research issue and the study relevant to me?' and 'Why does it matter to me?' with examples and stories to back-up the issue (Koen, 1985). Otherwise, it will be much harder to maintain their attention. Lastly, if the researcher is using numbers within the discussion, make sure those numbers are meaningful and, most importantly, memorable to them (McCready, 1998).

5.2 The HF and HCD awareness of the students at the commencement of action cycle 1

5.2.1 Classroom questionnaire

Final year maritime design undergraduates, who enrolled in the design project unit at the AMC, academic year 2015, were involved as participants of action cycle 1. In order to evaluate their understanding and awareness of maritime HF and HCD, a questionnaire was distributed to the students in the classroom. The students were invited through the faculty members and 35 students out of 65 were present. Open-ended, closed-ended, and scaled questions were included in the questionnaire (see Appendix B). They were given 20 minutes to complete the questionnaire. There was a total of 35 responses received for the questionnaire and none of those were rejected since the participants gave all the necessary information. Responses were analysed qualitatively using content analysis (Weber, 1990) and quantitatively using general statistics such as frequency and percentage using Microsoft Excel software. The majority of the students (24 out of 35) suggest they believed that if the users (seafarers) were well-trained and notify the potential issues, most onboard accidents could be eliminated. In addition, they did not recognise the significance of the HCD approach in ship design and suggested using designers' 'common sense' to design user-friendly ships. None of the students had been exposed to maritime HF or HCD-related topics during their undergraduate studies. However, nine students answered that the designers are responsible to 'design the problem out' (Khandpur, 2000) in the initial stages of the design (Abeysiriwardhane et al., 2014).

5.2.2 The review of previous design reports

I read and reviewed seven concept design reports of two previous undergraduate groups at the AMC (academic years 2013 and 2014). Those designs were preliminary concept designs of a yacht, an offshore patrol vessel, a multipurpose barge, two submarines, an offshore supply vessel, and a small research vessel.

All the design teams followed a similar report structure, which included explaining the main design drivers and methodology in the beginning of the reports. However, none of them considered HCD as the main design driver, although all of them mentioned innovation, greater fulfilment of the rules and regulations, stability, structural integrity and operational efficiency as main design drivers. None of the teams mentioned primary users of their designs. Furthermore they did not mention any tasks the users would perform or their operational conditions. Identification of secondary users was not at all considered as part of the designers' task in the concept stage itself. The consideration given to the human factor engineering requirements such as habitability, workability, maintainability and accessibility was very limited.

The yacht design team students provided two main cabins and one crew cabin within their design without having a clear idea of the number of crew and guests. However, by reviewing their design I understood that they were planning for approximately six crew members. It was not entirely clear whether all six crew would use one cabin or to whom these main cabins are designed for. Although the team mentioned that the vessel was going to operate in the Mediterranean Sea, they did not perform any seakeeping analysis. This convinced me that these students were not aware that the seakeeping performance of a vessel influences directly the overall performance of the seafarers' life including execution of onboard activities, sleep disturbances, and even sleep deprivation (Nocerino, 2010).

Most noticeably, both submarine design team students noted that the consideration of users and their tasks was out of their project scope, and they recommended including user-requirement considerations in the detailed design phase of their design. Furthermore, they recommended interviewing submarine users to find out their requirements.

The design team of multipurpose barge provided synchronised and automated systems within most of the areas of their design and they believed that it could completely eliminate human error.

> With synchronised and automated systems within this design, the human error factor can be eliminated and hence the safety is improved.
> — design team of the multipurpose barge.

These students were not aware that making automated ships alone is not sufficient for improving ship safety. Nor were they aware that one of the major challenges the maritime industry faces is improving the design of shipboard automation to provide effective interaction between crew and the automation (Rothblum, 2000). One of the concerns is that in seeking to increase the level of automation, one promotes the likelihood of human operators switching to 'habits of mind' (Louis & Sutton, 1991). This promotes a phenomenon called 'over-reliance'. Therefore these students must learn that the designers need to understand the human as an active component in the system.

The design team who did the concept proposal for an offshore supply vessel mentioned that the General Arrangement (GA) design is developed based on operability and crew workability. However, that was just limited to the wording. I did not find any analysis of the crew and their tasks in order to provide better design solutions within the GA design. Furthermore, they mentioned that they have provided stress-free access to the flight deck for patient transfer in case of casualty evacuation. Again, it was not clear in their GA how the access to the flight deck from the hospital room or other working areas of the ship was stress-free. This team decided to provide space for a gymnasium if only they could manage the space, and they recommended considering this within the future improvements of their design.

None of these design teams tried to analyse the working scenarios in situations such as loading provisions, moving heavy stores within the vessel, moving heavy spare parts within the vessel, carrying an injured person. They did not evaluate their designs with end-users or end user representatives at any stage of their designs. In addition, these teams did not show use of HF guidelines provided by classification societies or other maritime authorities as a best practice.

As a summary, the findings of the classroom questionnaire and the reviews of two years' previous design reports further confirms the common criticism of maritime design education, often articulated as biased towards the technological field, thus missing HF and HCD components (Abeysiriwardhane et al., 2014; Kuo & Houison-Craufurd, 2000; Lützhöft et al., 2017; Petersen, 2012).

5.3 Planning of actions

I enlisted support from an HF specialist to develop a detailed action plan of this research study. I was lucky to have an HF specialist in my supervisory team, who also had previous experience in delivering and conducting HF/HCD lectures and workshops. After discussions with the HF specialist, the following major steps were included in the action plan:

- Conduct HF-related onboard activities with students, allowing them practical experience of HF issues with current designs
- Deliver HF introductory lecture to all students
- Invite students to become HCD champions within their team, based on the teaching framework
- Deliver a yearlong scaffolding program based on the teaching framework – I referred to the academic calendar 2015 and identified 11 possible weeks without interfering with examinations, study leave and semester breaks. The following themes were then identified for the 11 weeks:
    - Familiarisation session with HCD champions
    - Introduction to HF, Ergonomics, and HCD
    - First step of HCD activities – Plan the HCD process
    - Second step of HCD activities – Understand and specify the context of use
    - Workshop on the context of use
    - Guest lecture by experienced seafarers
    - Third step of HCD activities – Specify the user requirements
    - Fourth step of HCD activities – Produce design solutions to meet user requirements
    - Fifth step of HCD activities – Evaluate designs against requirements
    - Designers meet end-users workshop
    - Introduce HF evaluation software

In addition to this, I planned to provide HF and HCD supportive materials, such as weekly pamphlets, reference books, research articles, electronic database references, useful video links and HF guidelines, to all champions. Furthermore, I contacted experienced seafarers at the AMC and through my personal contacts to make them aware of this study to enable me to request their support when necessary.

<u>Reflections:</u>

During this phase, it was vital to get the HF specialist's support to plan the theoretical content to be delivered during the HCD scaffolding program and to setup themes for the workshops. Furthermore, since the HF specialist is my primary research supervisor, she had very good understanding of my research. Though this situation made me happy, it could be completely different for other researchers. Since it is uncommon to have an HF specialist available within the research supervisory team or within the research group, a researcher may have to invite such specialist for getting support. One example of this is a team of researchers who worked together to develop a consolidated framework for the implementation of health services research findings into practice, took support from an outside expert panel to rate and evaluate the level of constructs of the framework (Damschroder et al., 2009), as the researchers were not experts in evaluating theories. Ado (2013) also brought experts in to guide early-career teacher researchers in her research study. One teacher in Ado's study commented that she would have been very worried if the experts had not been available to guide her. Petersen (2010), within his research study, also needed HF experts or ethnographers or anthropologists – someone who could make sense of what the users were doing, and to explain it in terms that were useful to managers and developers of hardware and software design of marine electronics.

Therefore, in such studies the researcher has to discuss with members of the research group or with colleagues to identify who are the available experts. Then they can use the cold-call approach (Crang, 2003) to sell, explain the idea and secure the experts' place within the research. If not, the researcher can ask another known expert whom they might recommend for an invitation. The researcher has to explain the research concern objectively, and the framework clearly, to the expert in order to receive the experts' correct input. This can be done by allowing plenty of time for questions and discussions with the outside expert (Karol & Nelson, 2011). Furthermore, the researcher also should inject her/his passion and vision in the discussion (Karol et al., 2011). Another important factor is whether it is appropriate to offer to pay expenses and an honorarium. However, it will depend on the level of support and the service the researcher is planning to receive. If the researcher can find a junior expert, they might be flattered to be invited (Karol et al., 2011), and would likely command a much lower fee, if any.

5.4 Implementing the action plan and data collection

5.4.1 Onboard visit

Four HF-related onboard activities were conducted with the participant cohort during a five-day voyage on board the AMC research vessel, Bluefin (see Table 5.1 and Figure 5.1). I requested that they record their feedback on record sheets (see Appendix C) once the activities were completed. All the activities were digitally recorded with the participants' permission. These activities were planned and conducted allowing maritime design students to practically experience HF issues within the design of ships, and to gain a better understanding of the practical aspect and the importance of HCD for seafarers' life. A total of 12 students participated and, from these, a total of 38 responses were received (activity 1: 10 responses, activity 2: 8, activity 3: 10, and activity 4: 10 responses). None of them were rejected since the participants gave all necessary information. Responses along with the videos recorded were analysed qualitatively together with field notes using the content analysis method.

Table 5.1: HF-related activities carried out on board the AMC research vessel Bluefin.

Activity	Description
1) Evacuate an injured person	Students were requested to carry an injured person on a stretcher from the machinery space to the main deck.
2) Check accessibility/operability of valves	Students were requested to observe the accessibility and operability of valves available in the engine room and the main deck of the vessel.
3) Check space utilisation	Students were requested to observe the space utilisation in accommodation, washroom space and recreation space and check if the design appropriately addressed the comfort of seafarers' lives.
4) Carry provisions through the ship	Students were requested to carry a medium-size provision box from main deck to stores then to galley and to garbage station.

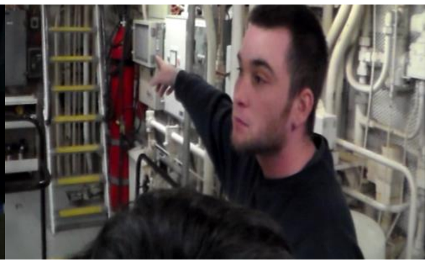
Figure 5.1: Students on board the AMC research vessel Bluefin during the briefing session of HF activities. (Picture used with consent)

The findings emphasised the significant contribution of an HF practical component integrated during this onboard visit to let students understand things by experiencing them (Luras & Nordby, 2014). When the students were given the opportunity to understand real HF issues by partaking (see Figure 5.2), the responses establish their eagerness of having a concrete HF knowledge during their studies. They tried different methods while carrying the injured person and sometimes realised that they failed in some methods due to the obstructions within the ship design, poor design consideration given to stairs and landing spaces and other design issues.

> I learned how difficult [it was] even assembling the stretcher. It also needs lot of patience. So imagine in such emergency situation if you are not able to carry the injured person safely, then you are so stressed. So I know how important [it is] to think these things [through] when we design layouts.
> —a student after the stretcher exercise.

Based on their personal experience after doing all activities, they realised the significance of including HF in the early stages of the ship design process. They identified issues and design improvements to advance the overall safety of the ship and comfort of the seafarers (see Table 5.2). As an overall summary, the students' HCD perspective was highly influenced by the onboard activities. Unlike the classroom questionnaire findings, 34 out of 38 responses provided positive feedback on the significance of including HF in the early stages of the ship design process. Furthermore, 25 of them requested to introduce this discipline in their degree course for them to gain in-depth knowledge. However, there were still a few students who did not recognise the significance of HCD in ship design and suggested using common sense to dictate the best compromise between comfort and efficiency. In addition, some of the students did not show interest in participating in these activities (Abeysiriwardhane et al., 2014).


5.2(a) 5.2(b)

5.2(c) 5.2(d)


5.2(e) 5.2(f)

Figure 5.2: An activity of students carrying an injured person on a stretcher from the engine room to the main deck of AMC research vessel Bluefin. (a) Assembling the stretcher; (b) Door obstructions while carrying the stretcher down to the engine room; (c) Strapping in patient; (d) Discussing different ways of carrying the patient; (e) Stretcher with patient almost vertical due to poor design of the stairs; (f) Door obstructions while carrying the patient to the main deck.
(Pictures used with consent)

Table 5.2: Design failures and improvements identified by students after HF-related onboard activities.

Design issues	Improvements
Current design has steep stairs	Redesign the stairs to reduce the steepness and increase the landing space and width.
Poor accessibility and operability of valves	Redesign according to the users requirements especially based on the operating frequency.
Poor accommodation layout design	Needs more privacy, space, storage space, improved headroom, sufficient natural light in accommodation.
Insufficient headroom everywhere	Increase headroom clearance throughout the ship.
Poor working environment	Users working scenarios have to be properly analysed before designing the layouts of ships.
Excessive vibration	Modifications need to be done to reduce vibration.
Cramped entry and exit points	Many entry and exit points must be modified.

Reflections:

The positive influence that the onboard activities had on the students' HCD perspective and understanding made me pleased. I understood the significance of providing future maritime designers with seagoing training within their undergraduate studies, and integrating such HF activities into their curriculum. Furthermore, I realised that the onboard activities are a good practical method to motivate technical people to follow non-technical matters and end up with usable designs, as other studies by Kuo et al. (2000), Petersen (2012) and The Nautical Institute (2015) have suggested. However, these suggestions were not investigated practically with the undergraduate maritime design students to validate their statement.

This five-day voyage was organised by the faculty members as part of one unit in the degree course. These students had to complete compulsory practical activities, such as performance sea trials, loading condition calculations, stability criteria calculations and trawling activities, within these five days. This could be the cause of some students showing less motivation to participate in these HF-related activities, since they are loaded with compulsory studies. Reflecting on the students' viewpoint on HF as designers' common sense, I understood that I must let the students understand that the 'common sense' is not common for all. Thus it was understood that this finding would have to be taken into account while preparing the introductory lecture and scaffolding sessions of this cycle, as well as onboard visits during action cycle 2.

5.4.2 HF and HCD introductory lecture

All students enrolled in the design project unit were invited to participate in this lecture. I invited the HF specialist to conduct the lecture and she accepted my invitation. During this two-hour session, the topics – including human error and maritime accidents, failure and success ship design examples, elimination of HF problems, HCD and usability – were delivered to the students, then later they were shown the videos taken during the onboard activities (see Appendix F for more detail). Besides that, the role of an HCD champion according to the teaching framework, and how to become one of them within the design teams, was also explained at the end of this introductory session.

Reflections:

Since I had to be directly involved in organising the class, time management and some lecturing during this introductory session, the flexibility I had for making notes in real time was limited.

Although this session was not compulsory, I noticed that the lecture theatre was full and that most of the students attended the session. Also, I noticed that none of them left the session early, which was a positive indication of the students' interest in introducing themselves to a new topic. In addition, a few of them engaged with the HF specialist when she was talking about basic approaches to eliminate HF problems, as identified by Khandpur (2000). Students asked the following questions related to the 'design the problem out' approach:

> What is the meaning of 'design for user'?
> What is the meaning of 'design for consistency'?
> How [do] we contact users to attain feedback?
> —students attended the HF introductory lecture.

Most interestingly, one student asked 'why these topics were not taught to us last year.' Such questions motivated me to prepare for the HCD knowledge dissemination program with confidence.

Also, the students who engaged more during the session were the students who participated in the onboard activities. This provided further evidence to me of the positive influence that the onboard activities had on the students' HCD perspective.

However, when the HF specialist showed a few pictures of risky situations and asked the students to give their opinions on how to eliminate the problem, the answers from a few students (4–5 students that I noticed) showed that still they were not ready to acknowledge the significance of the designers' responsibility to 'design the problem out' and were suggesting to get users to adapt to the design (see the quotes below).

> Let them wear safety shoes.
> Put visual labels, alarms or announcements out.
> Write good procedures, so they can read before they start the job.
> —students attended the HF introductory lecture.

The HF specialist guided them by explaining the right answer. Since these students did not have any exposure to topics like maritime HCD within their education, they might be thinking from the ordinary designers' perspective.

5.4.3 Invitation for HCD champions

The invitation flyer was sent to all students via the unit lecturer to recruit volunteers from design teams to become HCD champions. The invitation included all necessary information, such as what the students have to do as a champion, how they do it, and what they will get in return (see Appendix G). They were given one week to respond to the invitation. Out of the 14 design project teams, representative students from eight design project teams responded, showing their interest to become HCD champions in their teams (see Table 5.3). The scopes of the other six design projects were: numerical analysis of existing devices, such as wave and wake attenuating devices and wave energy converter devices; measuring and reproducing design drawings for two old boats; and wave spectral analysis for a sea pool. Thus the students from these groups were not interested in taking part in this research activity stating the limitations of HCD applications within their designs. As a result, out of 65, 41 maritime design students (eight champions and team members) were interested in participate the study as the first cohort.

Table 5.3: List of design projects included in action cycle 1.

Design project team	Design
T1	Anchor Handling Tug Supply (AHTS) vessel design
T2	Super Yacht design
T3	Offshore Decommissioning vessel design
T4	Sailing Super Yacht design
T5	Marina design
T6	Launching and Recovery System (LARS) design
T7	Redesign of existing vessel Bluefin
T8	Submarine design

<u>Reflections:</u>

I was aware of the importance of having alternative plans (Clark, 1972; Elliot, 1991; Feldman, 2007; McTaggart, 1993) if none of the teams had shown interest. The first alternative was to get support from the faculty members to motivate the students. As a second alternative, I planned to arrange extra onboard visits to show them the importance of the HCD approach in the design process. The third alternative was to arrange guest lectures by seafarers to present design issues they face during daily operations.

5.4.4 Familiarisation session with HCD champions

All the students who agreed to become HCD champions attended this session. First, I had a discussion with them about their design projects. Then I explained the research study, the pedagogical framework, the outline of the planned scaffolding program, and their role as an HCD champion according to the teaching framework. All the champions were happy to attend scaffolding sessions on Fridays from 09:00 am to 10:30 am, since Fridays from 10:30 am to 16:00 pm was allocated for the design project unit. They identified this proposed time as most suitable as it would provide strength to the HCD champion collaboration with team members as champions could work with their team member immediately after the HCD scaffolding session. I was happy to receive the consent from all the volunteered HCD champions. I briefed them on their responsibility to disseminate the knowledge they acquire through the scaffolding sessions to the team members in order to elevate the HCD knowledge of team members. Furthermore, I requested that they distribute the subject materials that would be provided during the scaffolding sessions to the team members and discuss with them the application of the HF and HCD knowledge within the design process. In addition, they were requested to provide authentic feedback and suggestions at the end of the scaffolding program so I could improve and modify the scaffolding and the teaching framework developed for the study. I invited them to work collaboratively with me. At the end of the session, I brought the following message for them to think about and cement their decision to become HCD champions:

> What if you try your best to learn [for] yourself first – and then guide your team members to develop their own understanding of the concepts – by attending this scaffolding program, then maybe in future you could be a HCD champion when you are in the industry. If you are ready, we are here to help you.

5.4.5 HCD knowledge dissemination activities – 'HCD scaffolding program'

The scaffolding program commenced a week after the familiarisation session with the HCD champions. A brief summary of each scaffolding session, outcomes, and reflections are discussed in this section. The relevant materials were distributed to the students at the end of each session. For a detailed explanation of each scaffolding session please refer to Appendix H.

<u>Session 1</u>

Topic: Introduction to HF, Ergonomics, and HCD.

Actions: A short lecture was conducted to explain HF, ergonomics, and the HCD approach. After the short lecture, the HF specialist introduced a class exercise to the champions, which was the 'Santa Clause Exercise' – imagine you are designing a workplace for Santa, which ergonomic/HF issues would you consider?

Outcomes: All eight champions attended the first scaffolding session and they were pleasantly engaged with the HF specialist for the discussions. Champions were taking down notes during the lecture which demonstrated their interest to take the things they learned during the session with them for future reference. During the class exercise session, the HF specialist requested champions think about Santa from the HF perspective if they had to design essentials for Santa. Most of the students figured out interesting points such as a safety helmet and specially designed shoes for the Santa who goes through chimneys, and a special magic key design for those who use doors, hand rails for the cart, special coffee machine design, and specially designed suits for the different areas and climates around the world. It appeared funny for a few of the students who did not engage with the HF specialist.

Reflections: Since the engineering students always work with numbers within a technical undergraduate program (McCready, 1998), some may have taken these examples as primitive, which made them reluctant to speak out. Nevertheless, there may be many other reasons for them to not engage. However, as an overall picture I have seen positive engagement from most of the students.

Session 2

Topic: First step of HCD activities – Plan the HCD process.

Actions: A short lecture covering the first step of the HCD activities was delivered.

Outcomes: Champions were taking notes during the HF specialist’s talk. A few champions requested the electronic version of the ISO (2010) standard document for them to go through. This showed their interest to read more about the HCD approach. The attendance was reduced from eight to six. According to those who did not attend, they had to attend a research group meeting.

Reflections: Since the HF and HCD components are not a compulsory part of their degree course, I should expect such situations where students give lower priority to the scaffolding sessions. I noted down in my research journal to brief them in the next scaffolding session about the topics discussed during this session to make sure that they did not miss the lesson.

Session 3

Topic: Second step of HCD activities – Understand and specify the context of use.

Actions: A short lecture covering the second step of the HCD activities was delivered. The discussion session after the lecture included the outlining of their design projects in order to initiate understanding of the context of use of their designs.

Outcomes: All champions attended this session. Similar to the previous session, the champions were paying attention to the HF specialist’s talk and took notes in their engineering diary, as noticed. A few champions (T1, T2, T6 and T8) inquired about anthropometric data tables for them to use in their designs. Most interestingly, a few champions (T1, T2, T4 and T8) requested that I provide the links to the HF videos shown in the first scaffolding session. Furthermore, they explained their team members’ interest in watching those videos. This session was more interactive at the end when the HF specialist asked students to brief us on their projects and to recognise the context of use (CoU). A few of them explained their projects clearly. Furthermore, three of those who talked about their projects further stated few primary users. For instance, the champion from the super yacht design team (T2) stated not only the yacht owner and guests but also the crewmembers, such as the master and chief engineer, as their primary users. The sailing yacht team (T4) champion also stated the yacht owner, guests and crewmembers as their primary users. The submarine design team (T8) champion also was able to talk about their primary users. Then the HF specialist requested that champions with team members study more to find out secondary users of their designs. However, there were one or two champions who did not state any few primary users. The HF specialist helped them to figure them out. At the end of the session, I talked to the champions who missed session 2, and briefed them of the topics discussed and showed them how to follow the documents I had distributed in the class. Within the allocated time for this session, the HF specialist did not have time to describe the methods of support to analyse the CoU. Therefore, I planned for another short session for the same topic in the following week.

Reflections: The outcomes provided evidence to show the effectiveness of utilising of 'discussion' pedagogic approach within traditional lecture context. It was collaborative and active learning session for students providing opportunity to discuss, ask questions, and apply content of the topic, resulting in deeper learning (Brookfield & Preskill, 2012).

Session 4

Part A

Topic: Continuation of the second step of HCD activities – Understand and specify the context of use.

Actions: A short lecture that covered methods of support to analyse the CoU was delivered. A discussion after the lecture session was conducted to support champions to understand the CoU of their designs.

Outcomes: During this session all champions made an effort to further understand and specify the context of use of their designs with the help of the HF specialist and myself. They explained why their design was needed, who will be the expected operators, the overall objectives of the project, key functions that the vessel would perform, the operating areas, and the environmental conditions. The attendance was reduced to five in this session.

Part B

Topic: Workshop on CoU – low fidelity (lo-fi) prototype workshop.

Actions: Champions and their team members were asked to build lo-fi prototypes of selected work scenarios on ships (see Table 5.4) and to prepare mobile phone videos of that scenario. A team of six experienced seafarers were available as end-user representatives for consultation. Once all teams finished with their designs and videos, representatives from each team presented the videos to the class, including end-user representatives. They then provided their feedback to students on each design (Abeysiriwardhane et al., 2015a).

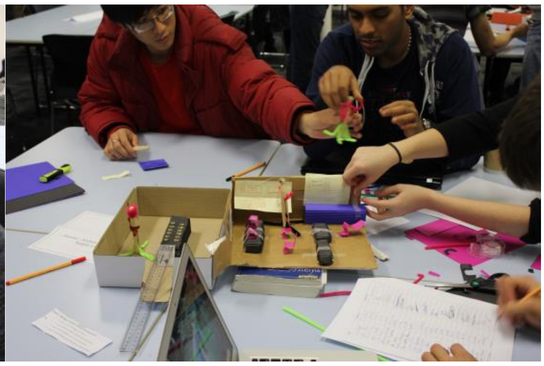
Table 5.4: Selected work scenarios on board ships for lo-fi prototyping workshop.

No.	Work scenario on a ship
01	Ship Bridge when arriving in a port
02	Ship Engine room (ER) /Engine control room (ECR) before departure
03	Ship mooring station preparing for arrival
04	Ship mess/galley preparing for the Captains Birthday
05	Ship life boat station conducting a lifeboat drill

Outcomes: Students prepared their lo-fi prototypes and videos for selected scenarios (see Figure 5.3). All end-user representatives (master mariners, chief engineers and safety instructor) were busy during the whole workshop, engaging with students (see Figure 5.4). The availability of the experienced seafarers during the session was helpful for most of the students to understand and improve their knowledge of CoU (see the following quote from one student).

> The workshop gave good insight on the equipment used during evacuation and the type of liferaft and lifeboats. Especially this allow[ed] me to search and find what the situation on board is [like] during [a] lifeboat drill and finally, [the] end-user's feedback on our designs was great.
> —a team member of T3.

5.3(a)



5.3(b)

5.3(c)

5.3(d)

5.3(e)

Figure 5.3: HCD champions and team members preparing the lo-fi prototypes of selected work scenarios on board ships. (a) Scenario 1; (b) Scenario 2; (c) Scenario 3; (d) Scenario 4; (e) Scenario 5. (Pictures used with consent)

According to the end-user representatives, the questions that the students asked were mostly related to the users, tasks, operational environment, and task procedures (Abeysiriwardhane et al., 2015b). Furthermore, the analysis of the students' feedback sheets indicated that 30 out of 50 participants recognised that to 'design the problem out' is the best approach to eliminating HF issues (Abeysiriwardhane et al., 2015b), which means that they were now aware of the possibilities to do so. Nevertheless, I noticed that a few teams were not really happy about the session. They were just having fun with the lo-fi materials and the videos that they made did not include any description of the CoU of the selected work context. Some students provided negative feedback on the workshop, declaring 'this workshop to be a waste of time', and 'Not the best way for final year students to spend time dedicated to work on their design projects.'

Figure 5.4: Champion and team members making use of end-user representatives' knowledge while preparing their lo-fi prototypes. (Picture used with consent)

Reflections: I realised that there are still students who are not ready to acknowledge the importance of having an improved understanding of the maritime context of use to design usable ships. I decided to take into account this matter while planning action cycle 2.

Session 5

Topic: Guest lectures presented by experienced seafarers.

Actions: Four experienced seafarers delivered short guest lectures. I invited all champions and their team members to attend this session.

Outcomes: I noticed that the lecture theatre was full of students. They all remained until the end of the session, which was a positive indication of the students' interest in listening to the end-user representatives' experience. Most of the students were taking down notes. I noticed that students were shocked when they hear from guest speakers how difficult it was for them to work in such poorly designed work places and they aided pictures they had taken on board (see below quote).

> The room can rise to over 45 degrees of Celsius. It is suffocating, it is hot, it is cramped, there is little air flow, and I have to work in there cleaning and maintaining for hours at a time.
> —a seafarer (guest speaker) talking about a purifier room.

At the end of the session, some of the champions and their team members talked to the guest speakers and they were requesting further explanations of critical tasks within different operational scenarios. This showed me the effectiveness of this session in aiding to improve the students' HCD knowledge. This was similar to the findings from the CoU workshop where students identified the importance of consulting experienced seafarers during the design process.

Reflections: I understood the effectiveness of inserting this 'guest lecture' pedagogical approach within traditional lecture context to enrich the overall learning experience of the students (Frederick, 1986; Gibbs & Habeshaw, 1989). It had given students opportunity to lean through real-world experiences of the guest speaker.

Session 6

Topic: Third step of HCD activities – Specify the user requirements.

Actions: A short lecture that covered the third step of the HCD activities was delivered. User requirements of the design projects of the students were discussed during the post-lecture discussion.

Outcomes: All champions attended this session. Champions pointed out habitability, maintainability and accessibility requirements based on their design projects including headroom in accommodation areas, overhead clearances in stairways in working areas such as machinery spaces, easy access to frequently operated valves, ventilation and heating requirements, private space for religious needs, workspace ergonomics, recreational space, sanitary facilities, locker room facilities, and easy walking routes of the ship.

Reflections: The engagement of most of the HCD champions on the subject matters was improving in each interactive discussion session. Most of them were able to articulate different points on each topic. Therefore, this pedagogic approach was helping students to practice and sharpen a number of skills, including the ability to articulate and defend different points related to the topic, and enlist and evaluate evidence (Brookfield et al., 2012; Davis, 2009).

Session 7

Topic: Fourth step of HCD activities – Produce design solutions to meet user requirements.

Actions: A short lecture covering the fourth step of the HCD activities was delivered.

Outcomes: All champions attended this session. Champions had shown their interest by asking questions and taking down notes while I was discussing crew habitability criterions, bridge visibility criterions, engine room layout ergonomic requirements, and HF guidance documents from classification societies and the IMO. In addition, all of them were pleasantly engaged when I showed them some success stories of HCD, such as an offshore wind farm support vessel design by Damen

Shipyard – 'walk to work (w2w) concept' – (Monchy & Smit, 2015), and a lifeboat design by the Royal National Lifeboat Institute in the United Kindom. When asked to create a story board (Nielsen, 1993) of a scenario – 'regular working day of a maintenance engineer on a w2w ship' – most of the champions engaged in the activity. They created a story board for the given scenario including the actions: have breakfast, get assigned tasks, change clothes, go to locker room, go to work desk, access turbine, do repair work, return to ship, go to locker room, debrief. At the end of the session, the champions requested more details on success stories for them to read through. One HCD champion (T1) talked to me after the scaffolding session saying that he and his team wanted to show and discuss their preliminary GA design. I highly admired the effort the team had taken to practice the HCD approach learnt during the sessions. I pointed out areas where they should further place attention to improve their design. The interesting fact that I recognised during the discussion with them was that all team members also had a good understanding of the HCD approach, which made me glad.

Reflections: I understood the influence of presenting real-world success stories of HCD and discussing them with undergraduates to make them engage with the topic as well as it brought authenticity to the classroom. Since real-world examples are inherently engaging and it was more tangible and meaningful to students (Duffy et al., 1993). Therefore, they become engaged in the discussion of the topic and improved their problem-solving skills, critical thinking skills, and it motivated them to find more examples (Cooperstein & Kocevar-Weidinger, 2004; Haack, 1972).

Session 8

Topic: Fifth step of HCD activities – Evaluate the designs against requirements.

Actions: A short lecture that covered the fifth step of the HCD activities was delivered.

Outcomes: All champions attended this session. Champions had shown their interest by asking questions and taking down notes while the HF specialist explained methods to evaluate the designs against user requirements. When the HF specialist was explaining 'user walk-through' as a method to evaluate the designs, champions expressed the difficulties in finding end-users to walk through their designs. I explained that I would support them in building contacts with the seafarers by organising a 'designers meet end-users' workshop for the following week's session. At the same time I requested that they prepare their layout designs in Two-Dimensional (2D) or Three-Dimensional (3D) form and to prepare any relevant questions to get the maximum benefit from the time they would spend with the seafarers.

Reflections: Attendance of the HCD champions was not reduced for the last four sessions, which I believed was a good indication of better peer collaboration.

Session 9

Topic: Designers meet end-users workshop.

Actions: A 'designers meet end-users' workshop was conducted for the HCD champions and their team members. On my invitation, a team of seven experienced seafarers were present as end-user representatives to provide HF feedback for improvement of the designs done by the students. The students facilitated a walk-through of their designs for the end-user representatives (see Figures 5.5 and 5.6).

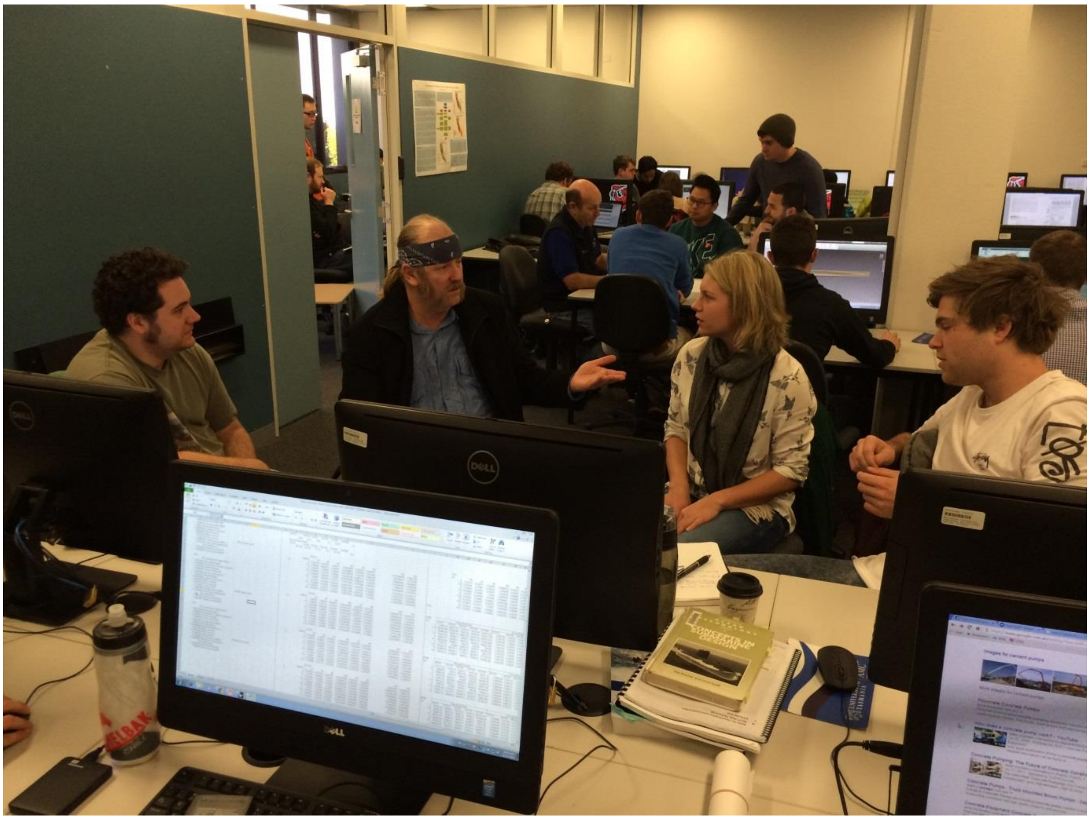


Figure 5.5: HCD champion and members of T8 are having a discussion with an end-user representative, a Submariner. (Picture used with consent)

Figure 5.6: HCD champion and members of T4 are having a discussion with end-user representatives, a Master mariner. (Picture used with consent)

Outcomes: Most of the teams were well prepared to meet the end-user representatives with their 2D design drawings, specifications and 3D models. It was very difficult for me sometimes to move the end-user representatives from one team to the next team, as students were requesting more time with them. This showed the students' interest in discussing their designs with the end-users, and thus to obtain their feedback to modify their designs. However, there were a few teams who were not well prepared for the walk-through of their designs, and they did not ask relevant questions to enable them to devise solutions to satisfy the end-user requirements, rather they tried to get the solutions to their design issues from the end-users. This was highlighted by few end-user representatives, and my observations supported this. In addition, the end-user representatives highlighted possible design alterations within the GA designs of teams and other layout drawings to make the designs more usable. Since this was the first such workshop arranged in the AMC, it was a novelty, and students not only appreciated the opportunity, but also requested to repeat such an event more frequently (see below quotes from students).

> Constructive feedback was given and advices from users [were] much appreciated. [It] gave us insight on stuffs [sic] that we may never [have] thought about.
> —a student after the session.

> We would very much like to have more meetings with users so that designers have a better overview of what users are experiencing with good design and bad designs, and we can design based on the user needs.
> —a student after the session.

> Can we have [a] 'designers meet end-users' workshop more often. It is really helpful. [Is there] any possibility to line up meetings with experienced seafarers throughout [the] design project?
> —a student after the session.

The faculty members were also present during the session. At the end of the session, they explained their observations during the workshop. According to them, this was the first time in the AMC's design project history that they saw such engagement from the students (Abeysiriwardhane et al., 2016).

Reflections: I personally spoke to teams who were not well prepared during the session and understood that they had not yet finalised the layout drawings. Although it was disappointing for me, I decided to take it as a positive indication to plan this valuable workshop during action cycle 2 when only the designers (students) were ready to meet the end-users. The time allocated for the scaffolding program and the design project was reaching its end and I understood that I would not be able to fulfil the students' requests to arrange more such workshops. However, I made a note in my journal to pay attention to this during the next cycle of this research. Ultimately, I understood the significance of setting up a stage for designers to meet seafarers in order to improve the designers' knowledge on the operational issues as well as to receive feedback to improve the designs. User feedback informs designers of the good features to be continued and developed, the failures and weaknesses, potential risks, and even ideas on how to improve them (Launis, 2001; Nielsen, 1993).

<u>Session 10</u>

Topic: Introduce HF evaluation software (HumanCAD®).

Actions: A short lecture covering the introduction to the HF evaluation software, HumanCAD®, was delivered.

Outcomes: All champions attended this closing session of the scaffolding program. One champion wanted to evaluate their design using the software, as he was ready with the 3D model. The other champions were not interested because they did not have enough time to prepare 3D models to evaluate using HumanCAD®.

Reflections: I made a note that I should motivate the champions of action cycle 2 to prepare only 3D models of the critical areas their designs, which could then be used with the software for analysis.

After this scaffolding session, two of the champions and their team members (T1 and T4) met again with the end-user representatives to discuss their drawings, revised according to the feedback they had received on the 'designers meet end-user' workshop day. This meeting indicated to me their interest in going through an iterative process to develop a good user-centred design, while appreciating the user requirements that I wanted to convince them of by conducting this HCD scaffolding program.

5.4.6 Interview with HCD champions, internet questionnaire to team members, and review of the design project reports

Individual semi-structured face-to-face interviews were performed with the HCD champions. All HCD champions were personally invited for the interviews by emails and all eight champions showed their interest to participate. Once they showed their interest, a date, time and location was fixed. The interviews were 20-25 minutes long and they were recorded upon obtaining the participant's consent. All questions were open-ended questions and are attached in Appendix D. Although I was prepared with a list of questions that were to be covered, I allowed the HCD champions considerable freedom in their responses. As explained in Chapter 4, Section 4.5, the disadvantages of conducting an interview as a data collection method was not an issue within this study, as the HCD champions gave their consent to participate in data collection activities at the beginning of the study. However, before starting the interview, I reminded them that they could decline to discuss any issues that made them uncomfortable.

The web link to complete the questionnaire was emailed individually to all team members except the HCD champions. The questionnaire included open-ended questions (see Appendix E). They were given two weeks to complete the questionnaire. In order to overcome the difficulty of returning the answers, I re-sent the questionnaire to one team member who did not answer after the allotted two weeks. Furthermore, to avoid misinterpretations, I gave clear questionnaire instructions at the beginning of the document. All questions were stand-alone and did not use terms that are not commonly understood throughout the population of students. I also attained their consent to participate in this data collection by making clear that consent is implied by participating in the survey. To gather the maximum possible data, I requested that the champions encourage their team members to participate in this survey activity. Upon obtaining the participants' consent, I collected design project reports of all eight teams through a faculty member and reviewed them individually.

5.5 Data analysis and results

5.5.1 Data analysis

As explained in Chapter 4, Section 4.6, I used a content analysis to analyse the data that I collected through both the interviews with the HCD champions and the questionnaires to the team members.

The individual interviews with the eight HCD champions were transcribed verbatim. While transcribing, I listened to the recordings several times to increase the accuracy of the transcript and to familiarise myself with the data. The unit of analysis (De Wever et al., 2006) of this study was the individual HCD champions. Then I read all eight transcriptions again to further familiarise myself with the data. Open coding was performed while reading and re-reading each transcript. I highlighted text and noted down as many headings, notes, thoughts and impressions as necessary to describe all aspects of the content, until no new points could be identified. When formulating categories, I identified that which was similar to be placed in the same category. The following key categories were formulated around the HCD champions:

- HCD understanding
- Experience as a peer leader in the team
- Motivation in practicing the HCD approach in the career
- Feedback and suggestions on the scaffolding program

Of the questionnaire to team members excluding the HCD champions, I received 30 responses out of a possible 33, and none of them were rejected since the participants gave all necessary information. Similar to the analysis of the individual interview data, I used an inductive content analysis method to analyse the questionnaire data. I read and re-read their responses several times while coding and the following key categories were formulated of the team members:

- HCD understanding
- Motivation in practicing the HCD approach in the career
- Feedback and suggestions on the workshops and scaffolding material
- Opinions on the HCD champions' facilitation and guidance

Furthermore, the marking rubric-A (see Chapter 4, Table 4.2) was used to assess the HCD understanding of champions and team members. All design project reports were read to assess the level of integration of the HCD approach during the design process based on the rubric-B (see Chapter 4, Table 4.3). Research journal notes were also read and re-read several times in order to familiarise myself with the data and used to develop the reflections of the actions and to compile what I learnt during this action cycle. These reflections are organised within the phases of the research to which they belong. Finally, relationships among the findings of the data analysis were identified in order to summarise the results.

5.5.2 Results

5.5.2.1 Team T1

<u>5.5.2.1 (a) Interview with HCD champion</u>

HCD understanding:

The HCD champion of this design team understood the HCD approach as a valuable design approach that focuses on making systems usable by applying HF and Ergonomics knowledge during the design. Furthermore, he stated the ISO (2010) guidance for HCD and explained the five essential steps of the HCD approach based on the ISO (2010) standard. He identified the insufficient consideration of the HCD approach within the traditional ship design spiral and recommended to modify it to include the HCD components. In addition, he explained the value of the designers' clear understanding of the situations in which the design would be used, to enable production of a usable design.

> If I do not know why I design this ship and [for] whom I design, and what is their operational environment, I will not be able to design it to [be] fit for users. I have to consider their requirements such as habitability, workability and maintainability. How can I minimise the obstructions within their walking routes and provide sufficient space and access for maintenance, and minimise work rounds?
> —champion of T1.

Further to this, he stated the consequence of user involvement and their feedback during the design stage to make user-friendly designs. He also stressed the significant support gained through HF guidance documents such as the ABS (2003a) and the MLC (2006). As a summary, he demonstrated a clear understanding of the HCD approach and the consequence of designers' HCD understanding in order to practice the approach. Yet, he did not discuss the challenges of practicing the HCD approach and the impact of those on the final design. Thus, according to the HCD understanding levels defined in the rubric-A, the HCD knowledge of the champion of T1 can be graded as Level 3.

Experience as a peer leader in the team:

He expressed the design outcome as a result of a team effort and appreciated the support given by all team members to include HF considerations into their design. He stated that all of his team members were motivated to apply the HCD approach because they participated in the first HCD introductory lecture and the onboard activities that were conducted on the research vessel, Bluefin.

> Three of us including me participated in [the] stretcher exercise and store transfer exercise on board Bluefin and identified lots of design issues seafarers are facing while working, due to bad design features. We, as a team, used to talk to each other about these design issues and tried to eliminate such in our design.
> —champion of T1.

He explained how he facilitated and guided his team members to practice the HCD approach throughout the project period by explaining what he learnt during HCD scaffolding sessions, distributing reading materials, showing them the useful videos and electronic pamphlets, and showing them the bad and good design examples.

Motivation in practicing the HCD approach in the career:

He stated his willingness to study more about HCD to have a comprehensive knowledge and to practice it further by doing more concept designs. He is eagerly waiting to use the HCD approach during his career. Furthermore, he mentioned the possible opportunities he has to influence his future design team members in applying the HCD approach with the champion experience he gained.

> This is the first time in my life I learnt HCD. I understand the significance of HCD and the application of it within the design. However, I would like to study much deeper. When I go back to my country I am pretty sure that no one [there has been] exposed to such [a] topic. I have the opportunity to further influence my future friends.
>
> —champion of T1.

Feedback and suggestions on the scaffolding sessions:

Firstly, he expressed his satisfaction of the delivery framework used within this study, and of the lectures, workshops, and guidance materials provided during the HCD scaffolding sessions. Further, he appreciated the effort taken to deliver such scaffolding sessions throughout the design project, especially being the first time at the AMC. In addition, he added the following suggestions to further improve the delivery of the scaffolding sessions to the next year's students:

- Discuss more examples of HF issues onboard ships as well as good designs
- Integrate HF and HCD theoretical sessions and practical sessions into the final year design project unit syllabus
- Arrange 'designers meet end-users' workshop sessions frequently

> Talking to people from [the] industry allowed us to visualise potential problems and practical solutions for those problem[s]. We realised that [was] real HCD approach. His feedback on our design was very valuable and he pointed [out] what we never really thought about.
>
> —champion of T1.

5.5.2.1 (b) Questionnaire to team members

HCD understanding:

All four team members responded to the questionnaire. All of them identified the HCD approach to maritime design as a fairly new design approach. They described it as an approach that can guide designers to incorporate end-user requirements into the design process to make the design fit for its users. According to their opinions, to make the HCD approach successful, the necessity of early consideration of the HCD approach into the design and end-user involvement throughout the process is paramount. All of them mentioned the benefits that seafarers may receive through the HCD approach, such as increased comfort in living; reduced stress during work due to proper ergonomic consideration in terms of vision, reach, space and access; and reduced potential to hazards. All four respondents explained the five essential steps that have to be followed by the designer, and two of them explained more into user requirements such as habitability, maintainability and accessibility. Similar to their champion, all of them stated the significance of the designers' understanding of the maritime HCD to design usable ships. Three respondents identified the other stakeholders, such as ship owners and ship builders, responsibilities, and the support they can provide in implementing the HCD approach throughout the ship's life cycle. However, none of them summarised the use of the principles of HCD approach to develop a user centred design through an iterative process. According to their responses, the HCD understanding of this group of team members can be graded as a Level 2 understanding according to the rubric-A.

Motivation in practicing the HCD approach in the career:

All of the respondents were indicating their willingness to apply the HF and HCD knowledge within their career that they acquired during the design project.

Feedback and suggestions on the workshops and scaffolding material:
All four team members stated the value of the learning materials, useful electronic databases, and relevant videos, which helped them to adequately learn why including HF into ship design is paramount, and how HCD should be practiced during the design process. Furthermore, all of them highlighted the value of the 'designers meet end-users' workshop and requested that more such workshops were arranged. In addition, their feedback was positive on the CoU workshop. All respondents highlighted the need of integrating maritime HCD knowledge into the maritime design students' education system.

> Lo-fi prototyping of a scenario helped to visualise and get a clear picture of the working environment and how people are doing their tasks onboard.
> —a team member of T1.

Opinions on HCD champion's facilitation and guidance:
All of them provided positive feedback for their HCD champion's facilitation to learn and practice the HCD approach during the design project period. They pointed out the champion's excellent guidance that was provided when they were struggling to solve issues in layout design. As they mentioned, the HCD champion was used to link team members with the facilitators and end-user representatives for further clarifications where necessary.

5.5.2.1 (c) Design project report review

This team had taken a decent effort to practice the HCD approach during the design process, which is reflected within their report. They identified the vessel deployment areas as the North-West shelf of Australia and the East Coast of Africa upon some research of similar vessels. Then they identified the minimum safe manning requirement as Master, First mate, Second Mate, Third Mate, Chief Engineer, Second Engineer, Third Engineer, three Dynamic Positioning Operators, three Integrated Ratings, and a Cook, again upon research of similar vessels. Furthermore, they defined three major operational cases, and identified tasks and the crew-demand associated with them (see Table 5.5).

Table 5.5: Context of use analysis of team T1; Four major operational scenarios, key tasks, and demand of the crew.

Operation	Task	Special crew
Deployment to gas field for supply duties	Bunkering/Loading, Transit, Offload Supply, Return Transit, Wash-down/Bunkering	Crane Operator, Dynamic Positioning Operator
Deployment to a platform for rig tow/anchor handling operations	Bunkering/Loading, Transit, Anchor Handling, Return, Wash-down/Unload	Crane Operator, Anchor Handling Winch Operator, Dynamic Positioning Operator
Deployment to any project for anchor handling & towing assist	Bunkering/Loading, Transit, Towing Assist, Anchor Handling, Standby, Towing Assist, Standby, Return transit, Wash-down/Unload	Crane Operator, Anchor Handling Winch Operator, Dynamic Positioning Operator
General	Launching and recovering ROVs and AUVs, Firefighting, Rescue	Divers, Maintenance Engineers (special personnel)

They mentioned a few iterations of GA design as per the HF perspective. The first iteration was done due to the limited visibility in the bridge and inadequate space within the superstructure for efficient and effective operation. The second iteration was done to incorporate accommodation requirements as per the MLC (2006) and other habitability requirements, such as the need for privacy, a place for religious activities, mess, recreational facilities, study room, gymnasium and storage space. They mentioned that they had a valuable opportunity to let an experienced seafarer and a naval architect to walkthrough their second iteration of the GA drawing and received remarkable feedback on improvements. Therefore, within the third iteration, engine room layout HF considerations were also considered for the following: space for maintenance; minimum obstructions; galley, mess and stores expansion; extended bridge wings for better visibility and controllability; and separation of working and living areas. They illustrated in the final iteration that:

> We want to be able to fit our design to all required people, spaces and systems, while positioning everything, keeping HF in mind, to promote [it] not only [as a] best working place at sea, but also [as a] home for seafarers.
>
> —AHTS design team (T1).

Their bridge design considerations ensured the field of view for the watchkeepers, the Dynamic Positioning (DP) operators and Anchor Handling (AH) winch operators, who all need clear vision on the stern deck. Hence the DP/AH workstations are given priority of the stern view, while the watchkeepers have good visibility of the bow for pusher operations. The outdoor deck enables observers to get a different perspective on stern deck operations (see Figure 5.7). This design exceeded the minimum requirements stated in the rule book (ABS, 2003b; Safety of Life at Sea (SOLAS), 2002) in terms of the navigation and manoeuvring workstation field of view. They provided washroom facilities on the next level below the bridge deck for those who work on the bridge.

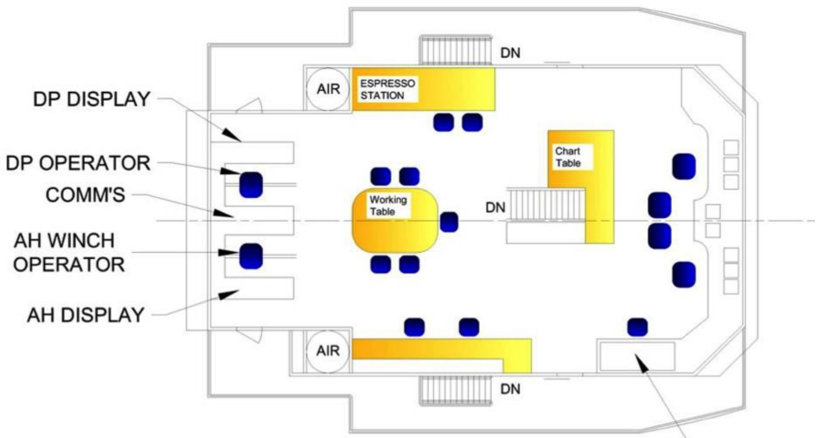


Figure 5.7: Bridge layout design of team T1. (Picture used with consent)

In order to separate working and living areas for minimum disturbance, they provided two full accommodation decks on the level below the bridge deck. However, due to space limitations, a few cabins were located at the main deck and galley deck levels, where two of them were located adjacent to the Anchor Locker compartment that can easily reduce the level of comfort. Nevertheless, they suggested using a noise protection insulation system for these cabins to reduce the discomfort level. All cabins designed for this vessel exceeded the MLC (2006) minimum requirements for the floor area. Also, the stairs and landing spaces were designed according to the HF guidelines of ABS to safely carry an injured person on a stretcher and provide convenient transport of heavy machinery equipment (ABS, 2014).

The design team made a significant effort to provide user-friendly logistical and personal access routes for provision loading to minimise the possible hazards while carrying heavy loads through walkways. They placed a telescopic crane on the forecastle deck to load stores from outside of the vessel to the dry stores compartment through a hatch. All the other storerooms were placed within close proximity to the dry stores to ease the logistics (see Figure 5.8). Not only this, placement of the galley with quick access to all stores was able to minimise the walking distance of the cook, thus reducing physical and mental workload (Hemmen, 2008). Furthermore, they placed the cook's suite on the galley deck level to provide the cook easy access to their most demanding working space (see Figure 5.8).

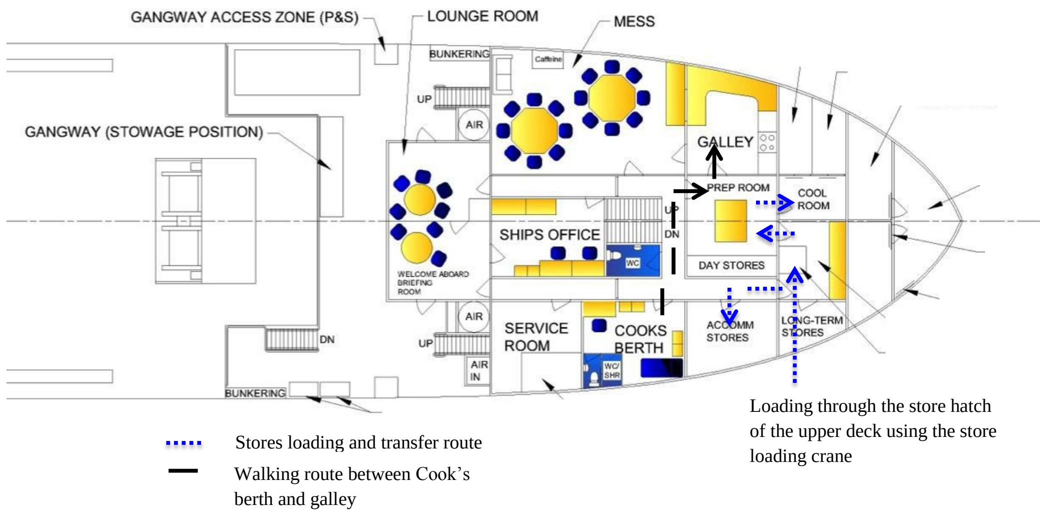


Figure 5.8: Design of logistical and personal access routes by design team T1 keeping user requirements in mind. (Reproduced with permission from the design team)

The design team identified the main deck as a hazardous working area and took an effort to improve the safety by reducing the obstructions, and providing two rail cranes on the sides that could be useful for easy operation. In addition, recesses were designed on the port and starboard of the stern deck that were located directly below the rail cranes and which ran for the length of the stern deck. As the vessel is intended to handle some of the largest oil rig anchors, it inevitably increases the risk involved in all operations. Should there be a mishap involving cables snapping, the personnel can then retreat into the recesses away from the danger. They provided quick access from the main deck to the wet room that had partitions for a locker room and a washroom. The engine room workshop and hospital are also placed close to the main deck entrance.

In summary, this design team have demonstrated a noteworthy effort to produce design solutions iteratively by incorporating user needs and their task-related requirements within the vessel's operational environment. Their effort to consider the user requirements of habitability, accessibility, maintainability, and controllability, and to follow HF guidelines during the design process, was noteworthy. Furthermore, this team took a notable effort to design user-friendly logistical and personal access routes for their users by linking tasks and user working areas which may lead to minimise stress, fatigue, and potential hazards (Ellis, 2009). However, they did not utilise the additional HF analysis methods such as ergonomic evaluation tools to re-evaluate the design, as introduced during the scaffolding sessions separate to the feedback received from the users. Also, they did not discuss all of the primary user tasks or any of the secondary users, and did not justify the trade-off between their design solutions and user requirements. Accordingly, the application of the HCD approach during the design process of this team can be graded as Level 3 integration according to the rubric-B.

5.5.2.2 Team T2

5.5.2.2 (a) Interview with HCD champion

HCD understanding:

The champion identified the HCD approach as a valuable design drive which focuses on making systems usable by applying end-user requirements into the design process. He explained five essential phases of HCD based on the ISO (2010) standards. The champion further identified the benefits seafarers receive if the designers practice the HCD approach and explained as below.

> If we design [a] user-friendly ship considering user requirements, then it will reduce the obstructions during operation, long distances they have to run back and forth every day to perform a single task and lots of other issues. This will ultimately minimise operators stress, fatigue, and increase efficiency and satisfaction.
>
> —champion of T2.

He specified the importance of involving end-user representatives throughout the design process to make more usable designs through the iterative process. Furthermore, he explained that if the ship is to operate effectively, the designer must consider the provision of adequate and comfortable accommodation, including furnishings, washing facilities, galleys, mess rooms and recreational spaces.

> We looked at similar designs to find out bad and good design features. I remember we found one similar vessel which had four people sharing [a] cabin and the size was 1.2m wide and just 4m across. That was definitely not a better place.
>
> —champion of T2.

In addition, he mentioned the HCD approach is not only to provide comfort but also to consider maintenance spaces; accessibility of the most demanding spaces of the design, such as stores; good working flow in control stations with minimum obstructions and appropriate manoeuvring capabilities. Furthermore, he explained how he practised HCD during the design project. Identification of the users, tasks and the vessel operational environment was highlighted by the champion as the first step. Then he explained the consideration given to user requirements by providing easy access and user-friendly working environments especially within the engine room, bridge, mess, galley, and deck. He also explained about designing internal spaces with logistical and personal access in mind. His explanation and discussion showed a sound understanding of the HCD approach as presented within the scaffolding sessions. Accordingly, the understanding of HCD champions about the HCD approach in maritime design can be graded as a Level 3 understanding according to the rubric-A.

Experience as a peer leader in the team:

This champion was truly satisfied with his HCD champion role, which provided guidance and support to his team members to acquire new knowledge and skills. Furthermore, he recognised the design outcome as a result of a team effort because all of his team members were appreciative and enthusiastic about applying the HCD concept from the beginning of the project.

> My team mates were well enthusiastic after participating the onboard activities and the introductory lecture. Therefore, there was not much motivation needed for my team members during the project period but sometimes I had to remind them. I personally enjoyed my role because I provided guidance when they [were] lost. I was the mentor, sort of, in my team.
> —champion of T2.

After every scaffolding session, he explained the HF and HCD topics to his team members and distributed the reading materials and useful links, such as library e-book links, electronic database links and HF guidelines, in order to disseminate what he learnt from the scaffolding sessions. In addition, he stated that since the team members were looking after the design of different sections of the vessel, he guided them all to apply the HCD approach carefully.

> As an example, when my team mates have questions on the working scenarios onboard and people interaction within the ship bridge, I provided assistance to find out answers (showed them Alert videos) and I guided him to ask relevant questions when we [met the] facilitators and end-user representatives.
> —champion of T2.

Motivation in practicing the HCD approach in the career:
He was willing to apply the HF and HCD knowledge, that he acquired during this program, in the future to design usable ships.

> I personally recognised HF as a joke. I thought it is common sense. But when you said during the introductory session 'common sense is not common for all' with some serious examples, that changed my mind. No doubt that all designers must take this approach into consideration, if he or she wants to make both users and client happy. I will make sure I always consider HCD in my career.
> —champion of T2.

Finally, he stated that he would definitely use the experience gained as an HCD champion to motivate and guide team members in his future design teams.

Feedback and suggestions on the scaffolding sessions:
The champion was gratified with the scaffolding sessions and expressed his satisfaction on the workshops and guidance materials provided. In addition, he stated that weekly scaffoldings sessions were arranged at a perfect time slot, that is, just before the weekly design project team meetings, enabling champions to effectively disseminate the knowledge to the team members. The following suggestions were given:

- Discuss extra examples of HF issues onboard ships
- Assign an end-user to engage with the team throughout the design process, or arrange more workshop sessions to meet end-users

> It was exceptionally valuable for me and my team mates, and that was the most valuable hour we [spent] during [the] design project time. It was beneficial to hear from real users about their tasks and operational issues they face so we can think how to avoid them during [the] design stage. His feedback on our design solutions was invaluable and he mentioned what we never really thought about.
> —champion of T2.

- Include HF and HCD theoretical sessions and practical sessions into the final year design project unit syllabus

5.5.2.2 (b) Questionnaire to team members

HCD understanding:

All five team members responded to the questionnaire. Similar to their HCD champion, all of them heard about the HCD concept for the first time in their undergraduate studies, during the final year design project. Furthermore, all of them identified the HCD approach as a key design driver, which can make systems usable by taking the user requirements and the user capabilities into account. They mentioned that the design solutions have to incorporate the user requirements, such as habitability, workability and maintainability, to produce a user-centred design.

> If the user has to run back and forth all the way to grab something daily then our design is crap.
> —a team member of T2.

All of them explained the CoU analysis as the key to find out users of the design, their tasks and the operating environment in order to understand and specify the user requirements. In addition, two of them stressed the need to include the HCD approach in ship design spiral to ensure all the designs are being fitting to the context of its use. Besides that, all of them stated the benefits that the crew would receive by incorporating the HCD approach, such as reduced crew/guests discomfort, stress, fatigue, inconveniences and inefficiency. Though all of them defined and discussed the HCD approach and its importance acceptably, they did not summarise the use of the principles of the HCD approach to develop a user-centred design through an iterative process. Hence, the HCD understanding of this group of team members can be graded as a Level 2 understanding according to the levels categorised in the rubric-A.

Motivation in practicing the HCD approach in the career:

All respondents showed their motivation to continue the use of the HCD approach in their future designs, as they identified its benefits to the end-users in enabling them to perform their jobs easily, safely and effectively. Furthermore, they highlighted the design team support as a key factor to being successful in this approach.

> HCD will be a strong aspect of my designs in future. Now I know if I [want] to satisfy the users of my design I must practice the HCD approach from [the] start of the project. This is not only to satisfy the user but also [for the] good reputation for the designing company. However this [needs a] highly motivated team.
> —a team member of T2.

Feedback and suggestions on the workshops and scaffolding material:

All respondents stated the exceptional value of the ‘designers meet end-users’ workshop, where they received valuable feedback and suggestions on their designs for vast improvement. All of them appreciated the HF and HCD learning materials they received through their HCD champion. Two of them provided positive feedback on the CoU workshop. Both of these two respondents were able to imagine the real situation and the operational environment through low fidelity prototyping with manikins. Other two students were suggesting to utilise the time allocated for preparing lo-fi to plan other useful sessions like meeting end-users. They mentioned a few suggestions as:

- Arrange more ‘designers meet end-users’ sessions
- Upload the scaffolding material and useful links to a shared folder where all students have direct access
- Talking to end-user representatives during the CoU workshop was valuable. Otherwise, a waste of time
- Include HF, HCD theoretical and practical sessions into the final year design project unit syllabus

Opinions on HCD champion's facilitation and guidance:
All respondents identified the HCD champion as their mentor in HCD implementation, as he was attending the scaffolding sessions. They took the support and guidance from the champion in HF integration into the design process. Furthermore, all of them appreciated the champion's ability to effectively disseminate the knowledge he had gained from the HCD scaffolding sessions using the following methods:

- Explaining the topics learnt from each HCD session
- Distributing the HF and HCD materials
- Showing the locations of electronic databases and useful videos to team members

All of them provided overall positive feedback for their HCD champion's facilitation to practice the HCD approach during the design.

5.5.2.2 (c) Design project report review

Upon reviewing their design project report, I observed that this team had taken a noticeable effort to practice the HCD approach within their design process. The students identified the following key expectations of the yacht owner:

- Ultra-modern inspiration similar to the Admiral-Impero yacht range
- Ability to navigate through the Panama Canal
- Accommodation for 12 guests and 15 crew members.

They identified their primary users as the yacht owner, guests and the crewmembers, and listed the identified tasks as shown in Table 5.6.

Table 5.6: Context of use analysis of team T2; Primary users and their tasks.

Primary users	Tasks
Yacht owner and guests (12)	'Spend the days' within a relaxing and peaceful environment with ultimate pleasure Get together with family members and close friends Sightseeing tours around the world
Captain and staff	Navigate and manoeuvre the vessel Berthing and mooring operations
Chief Engineer and staff	Maintain the vessel and its machineries Carry out daily checks
Head chef, Sous chef and staff	Provide respectable and fast service during functions. Stores loading and logistics

They have made a good effort to provide ultra-modern inspiration (McCartan et al., 2011a, 2011b) for the yacht owner and guests by providing a lot of luxuries in the design. To mention a few, an internal upper dining room with a spectacular view for more private dinners on the bridge deck, an external sun deck with a central fireplace, a private deck for the owner including two guest suites, entertainment deck, gallery, fully-equipped gym, pool, tender and jet ski boat bay.

> The Master Suite consists of every feature you would find in a penthouse suite. There is a study, lounge area, large bathroom, his-and-hers walk-in wardrobe, external wings, and an internal sunbed. The master suite itself is located near midships where there is reduced vessel motion in all conditions. The Master's Private Deck is accessible through the forward door in the superstructure. The private deck is supplied with a diverse variety of seating and is surrounded [by] an open chrome handrail wrapping around the bow.
> —super yacht design team (T2).

The students' effort to provide better comfort not only to the owner and guests but also to the crew members was notable. They were provided with three larger private suites, four shared suites, four communal closets, a private crew mess and recreational facilities. However, two crew cabins were located adjacent to the engine room bulkhead, which was not acceptable. Yet, they identified the discomfort to the crew in these cabins and stated a few solutions, such as to select main engines, generators and shafts for which the noise and vibration can be reduced, and to use soundproofing materials (Megasorber Acoustic Foam) for noise reduction.

They mentioned that they got a valuable opportunity to let a yacht-experienced seafarer to walk through their GA drawing and received remarkable feedback for improvements. Based on the feedback from the end-user representatives and the study of similar yacht designs, the crew cabins of this design were placed at a different deck level with separate recreational facilities and mess to separate the crew area from the owner and guest areas. This design decision was made to provide freedom for the owner and guests to fully enjoy the intimacy of the areas designed for them, with the crew areas having fully independent access. However, due to the lack of space in top deck levels, they had to place four guest cabins in the crew accommodation deck. But these four cabins were separated from the crew area and a separate access from the guest area was designed to access them.

During their design process, they made a considerable effort to design all internal spaces with logistical and personal access in mind. They provided an easy logistical and personal access routes for the cook by keeping the galley, cool and dry stores, waste room, main dining room, bar and lounge on the same deck, which they named as the entertainment deck. They included a small tender boat, which could be used to reach islands, supply provisions, or transport machinery spares for maintenance. The day storage was placed very close to the tender bay, from where stores could be transported to the crew mess located on the same deck level, and to the main kitchen at the next deck level via the stairs (see Figure 5.9). In addition, the design provided a quick access to the wet room next to the tender bay, where the guests could clean up before moving to their cabins or lounge area to get ready for their next event (see Figure 5.9).

The design comprised a crew office, engine workshop, engine stores and engine control room on the same deck, providing an easy working environment for the engine department crew (see Figure 5.9). The workshop and engine room stores were given an easy access from the tender bay via stairs. The stairs were designed with a 38 degree angle according to the guidance provided in the ABS (2014). The landing spaces of all stairs were also designed based on HF guidelines to provide convenient transport of heavy machinery equipment and to safely carry an injured person on a stretcher. The machinery space layout provided enough servicing room for the engineers to carry out their daily checks and maintenance. The chief engineer and second engineer were provided with easy access to the machinery and control spaces from their cabins (see Figure 5.9).

In order for the captain and bridge crew to have easy access and visibility around the vessel, the bridge comprised of port and starboard wings with additional navigation controls connected by an external walkway around the front of the bridge. The main control panel bench was predominantly transverse, with the pilot seats electronically retractable. This layout with the unobstructed walkway behind the pilot seats reduced the traffic and allowed the crew to operate and move about the bridge easily. The two outboard chart tables were free of passage obstruction and the walkway behind the plotting bench was wide enough to allow crew to pass behind. The bridge was also equipped with its own toilet, for quick access for the crew, to reduce time away from their tasks. The captain’s quarters was located aft of the bridge for quick access for any spontaneous operations or situations that may arise.

> The functionality and practicality is important not only for the guests but also the captain and onboard crew. —super yacht design team (T2).

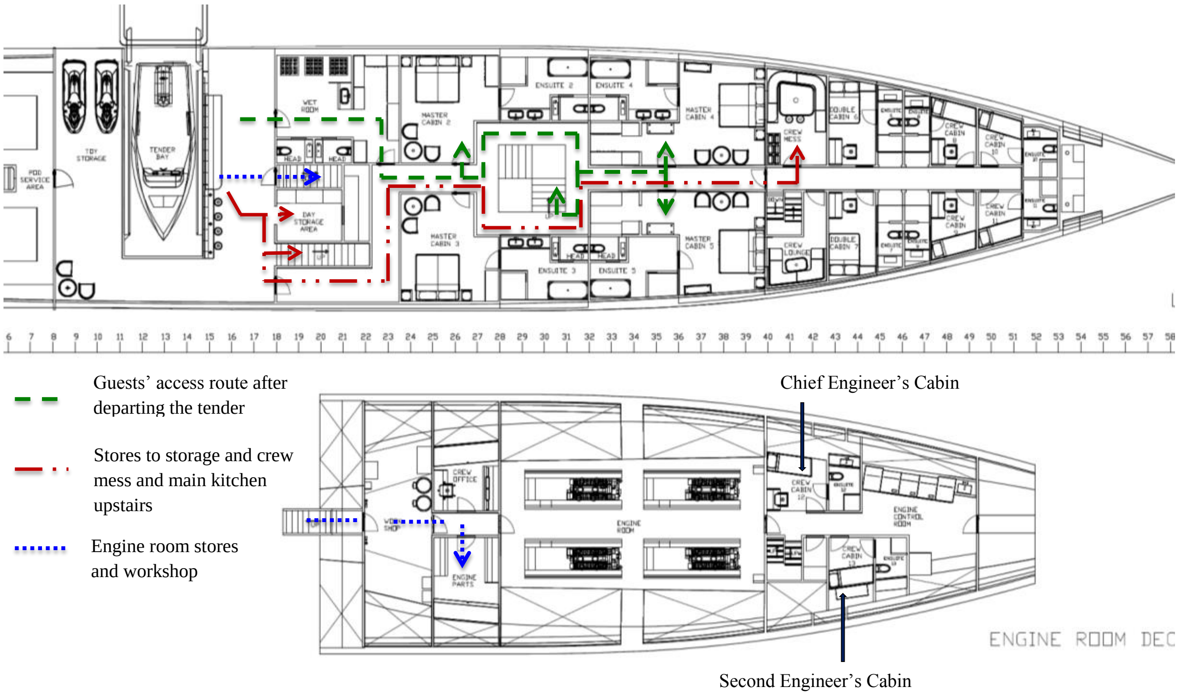


Figure 5.9: Design of logistical and personal access routes by design team T2 keeping user requirements in mind. (Reproduced with permission from the design team)

However, their bridge windows were designed to be vertical, which is not acceptable according to regulation 22 – Navigation bridge visibility (Safety of Life at Sea (SOLAS), 2002). The design considered controllability and manoeuvrability requirements by selecting a proven hull shape (Sea Axe Bow Design), which reduces peak acceleration by 50% over other hull shapes (Gelling, 2006). Azimuth and tunnel thrusters were also used. This design decision may have significant impact on improving the end-users’ workability and life on board the vessel.

As a summary, this design project exhibited a noteworthy commitment to incorporating primary users and their key tasks in considerations as a basis for the design decisions; however, it lacked sufficient identification of each user’s individual tasks and user responsibilities, rather only focusing on their key tasks. In addition, they have not identified secondary users of their design. They did recognise the frequency of many tasks, such as the requirement for the engine room crew to access the engine room and engine control room, and the chef’s frequent and demanding jobs in the galley, mess and entertainment areas. Thus, they have taken a noteworthy effort to design user-friendly personal access routes for the engine crew and the chef by linking tasks and the working areas. Furthermore, user requirements such as luxury, habitability, accessibility and the bridge visibility were adequately discussed and justified in the trade-offs between user requirements and design solutions. Accordingly, the application of the HCD approach during the design process of this team can be graded as Level 3 integration according to the rubric-B.

5.5.2.3 Team T3

5.5.2.3 (a) Interview with HCD champion

HCD understanding:

The champion of this team explained the HCD approach to maritime design as a systematic approach that can guide any maritime designer to consider the end-user requirements within the design process in order to 'design the problems out' rather than 'train the operator' to manage the problems. Furthermore, she explained that if the designer is trying to 'adapt users to the system' as found in the traditional design process, the design will not be usable. However, if the designer is trying their best to 'adopt system to the users', then the design will receive good user feedback. In addition, she explained the five essential steps in the HCD approach and highlighted 'understand and specify the context of use' as the most time consuming step. She further added the importance of end-users' involvement to identify the tasks and the real operational environment to understand and specify the CoU.

> User involvement into the HCD approach must be throughout. It specially support[s] analysing the context of use. As designers who do not have seagoing experience, I feel we need a huge support from seafarers to identify issues. Sometimes looking at similar designs and videos to identify users and tasks and operation indeed helps, but not adequately. This is a huge challenge within HCD approach.
>
> —champion of T3.

She identified the HCD approach as an important approach that every designer should follow. She specified that most designers failed to appreciate the HCD approach and thus, changing their 'mind-set' would be challenging. She further explained that since her design team members did not appreciate the HCD approach, it was hard for her to convince them to consider user requirements during their design.

> Different sections of the final design are [being] look[ed] after by different designers. If all of them are not running towards the same goal, then that design will be a less user-friendly design.
>
> —champion of T3.

She suggested standardising the HCD approach as a provisional solution to push designers to use that, though she identified changing the 'mind-set' of the designers as the long-lasting solution. Her explanation and clarification of the HCD approach, its application and challenges, and the significance of designers' appreciation in HCD, demonstrated her sound understanding on the HCD approach in maritime design. Thus, the HCD understanding of this champion can be graded as a Level 4 understanding according to the levels categorised in the rubric-A.

Experience as a peer leader in the team:

This champion did not have positive feedback on her experience as a champion due to the lack of support and appreciation from her team members to apply the HCD approach. Therefore, finally HF integration into the design became her responsibility, rather than a team effort.

> My team members considered HCD as mostly common sense. They thought [of it as] not required as it [is] not included in the unit content. This was [an] additional headache for them and finally it was all of my effort.
>
> —champion of T3.

Motivation in practicing the HCD approach in the career:
According to her explanation, the motivation, guidance, and facilitation received throughout the scaffolding sessions stimulated her knowledge and helped her to understand the value of HCD for the users' health, well-being, effectiveness, and efficiency of the whole system. Therefore she was willing to practice the HCD approach during her career.

Feedback and suggestions on the scaffolding sessions:
The champion was really happy with the scaffolding sessions and expressed her satisfaction on workshops and the reading materials provided.

> The scenario we have chosen for prototyping was 'ship lifeboat station is doing lifeboat drill'. I personally did not have any idea about [a] lifeboat drill and how it is usually perform[ed] on board [a] ship. We made our prototype after little research and advice received from safety officer and seafarer. At the end of the session, it made me to think about the real situation on board ship during lifeboat drill, [and] how evacuation routes, muster station location [affect] end-users' performance in emergency situation.
> —champion of T3.

However, she specified the following suggestions to improve the scaffolding sessions and to further increase the students' engagement in applying HCD:

- Discuss extra examples of HF issues onboard ships and offshore industry
- Arrange guest lectures by seafarers of different expertise such as offshore
- Include HCD into the design project unit syllabus as a key design driver

5.5.2.3 (b) Questionnaire to team members

HCD understanding:
Three out of four members of the design team provided valid responses to the questionnaire. All of the responses mentioned that the HCD approach is designers' common sense. It exhibited the inappropriate understanding, hence, their understanding of the HCD approach can be categorised as a Level 0 understanding according to the rubric-A.

Motivation in practicing the HCD approach in the career:
Team members' responses did not indicate their motivation to practice the HCD approach in their career.

Feedback and suggestions on the workshops and scaffolding material:
There was no feedback or suggestion provided by the team members to improve the workshops and the scaffolding materials.

Opinions on HCD champion's facilitation and guidance:
All three responses were very short and stated the champion's enthusiasm in integrating HCD into their design project.

5.5.2.3 (c) Design project report review

The purpose of the vessel was identified as to carry out the decommissioning of redundant offshore installations in water depths of between seven and 50 metres. The key work tasks of this vessel were identified as:

- Arriving on site after the offshore oil well has been plugged and abandoned

- Lifting and embarking both the topside module and jacket
- Transporting them to an onshore site for further disassembly
- Supporting transport and installation of new offshore platforms
- Deploying, and support for, ROV operations

The expected operating area of this vessel was mentioned as the Gulf of Mexico, the North Sea and Southeast Asia. In addition, the concept proposal included primary users: the captain, deck staff, chief engineer and engine staff, and special personnel – maintenance personnel, decommissioning personnel, offshore engineers, and clients who will be onboard for special meetings.

This concept design proposal exhibited good effort to provide a decent living environment to the end-users including special personnel. The design included 144 double cabins, 100 single cabins and 8 special cabins for clients, the floor areas of each of these cabins exceeding the requirement of the MLC (2006) (see Figure 5.10). The standard single cabin contained a king single bed, desk, wardrobe, chest of drawers, television, and an ensuite with shower.

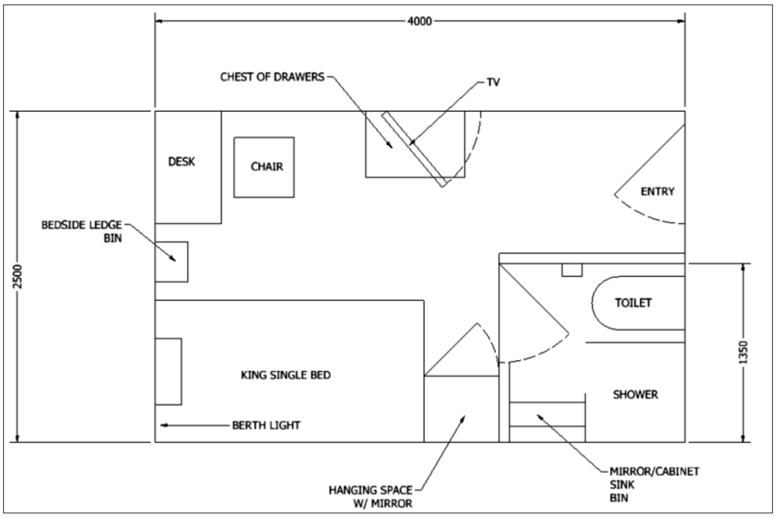


Figure 5.10: Layout design of a single cabin by design team T1. (Picture used with consent)

The design has the living area separated from the working and recreational area by spreading all cabins over four decks. Furthermore, all recreational facilities such as gym, internet cafe, sauna, senior/junior officer day room, galley and mess were placed on one single deck. The deck height was designed as 3m to provide acceptable headroom clearance. The superstructure at main deck level layout provided easy planning for the daily work on deck since it included meeting rooms, offices, changing rooms, drying room and relaxing room all at this level. In addition, the hospital and medical office were placed at the main deck level where an injured or sick person can be carried quickly and easily to the hospital.

The design team had taken a good effort to provide user-friendly logistical and personal access routes for the provision loading on to the vessel as to minimise the possible hazards while carrying heavy loads through walkways. The provision loading room was placed on the main deck and goods can be loaded using the deck crane. Main freezer and dry provision stores were located on one deck level below the main deck. The elevator placed close to the loading point to transfer provision from the provision loading room to the main stores. A day store was located in the galley making easy walking path for the crew to transfer the provisions. Also, the stairs and landing spaces were designed according to the guidance provided in the ABS (2014) to safely carry an injured person on a stretcher and provide convenient transport of heavy machinery equipment.

This impact of the bridge design to the safe and efficient operation of the vessel was identified during this design process. Their report mentioned as follows.

> Small variations in bridge design keeping HF in mind can significantly hinder or enhance crew performance.
> —decommissioning vessel design team (T3).

Navigating, manoeuvring, monitoring, route planning, docking, search and rescue operations and deck operations were all identified as the major tasks of the bridge crew. In order to provide an easy and better workplace for the bridge crew, the design placed main navigation and manoeuvring workstation at the centre and most forward to provide better visibility. Docking, and search and rescue workstations were located at port and starboard sides of the vessel providing easy manoeuvrability during slow cruising. Most interestingly, this proposal design suggested placing vessel positioning displays such as radar, global positioning system (GPS), radio navigation systems and depth monitoring system close to each other to encourage users to compare their readings easily. This suggestion was based on the understanding through the literature on MV Royal Majesty grounding report. The incident could have been avoided if the bridge officers compared the radar, GPS, and radio navigation system readings consistently, if a key alarm had been audible, or if the depth meter had been used (Degani, 2004). This design exhibited the notable effort to design a better evacuation system to allow efficient muster and abandonment. Lifeboats were easily accessible from every level of the superstructure. In addition, the design took care to minimise the distance and number of turns required to move from any point on a given deck level to an outside walkway with access to lifeboat. These design decision were made based on the feedback received from the end-user representatives.

In summary, upon reviewing the design report, it can be identified that this design proposal had taken into account the primary users and their key tasks based on the operational requirements of the vessel, though less effort was made to analyse CoU in detail. The effort to consider user requirements such as habitability, accessibility, controllability and survivability was noteworthy. In addition, the effort taken to design user-friendly logistical and personal access routes for the users was made important by linking some of the tasks and user working areas that may lead to minimise the potential hazards. Accordingly, application of the HCD approach during the design process can be categorised as Level 3 integration according to the rubric-B.

5.5.2.4 Team T4

5.5.2.4 (a) Interview with HCD champion

HCD understanding:

The champion of this design team described the HCD approach to maritime design as an approach that looks at the ship design from an operator's perspective. Further, he explained the five essential phases of HCD according to the ISO (2010) standard requirements and recommendations. In addition, he identified the importance of integrating the HCD approach into the traditional ship design spiral, which has no HCD presently. He compared the traditional ship design spiral and the HCD approach by highlighting the following points:

- The HCD approach in ship design gives more focus on user satisfaction

- Designers must appreciate the seafarers' tough, risky and uncomfortable working conditions when using the HCD approach
- Designers who follow the HCD approach must consult seafarers
- Designers who follow the HCD approach should at least have foundation level of maritime HF and HCD knowledge

Furthermore, he stated the possible benefits that the ship design companies may gain through the HCD approach that could increase the clients' satisfaction when operators are pleased and effective within usable designs. According to his description, in order to proceed with the HCD approach, the users and major tasks must be clearly identified at the conceptual design stage. Then the user requirements must be considered and the user evaluation has to be performed to assess the design. Furthermore, he expressed the following understanding about the CoU analysis within the design process.

> CoU analysis for small vessels could be easier than [a] complex big vessel where more people work and [there are] more tasks to be performed. However, small vessel designers have to struggle a lot with the space and it is challenging when trade-off discussions comes into play. This is exactly what I faced during [the] accommodation layout design.
>
> —champion of T4.

In addition, he specified the HCD approach as a guide to the ship designers:

> The HCD approach can guide us to consider HF and ergonomic requirements into the design from the concept. This is how I keep HCD in my mind and it [does] remind me [of] the importance of it.
>
> —champion of T4.

Finally, he explained how he and his team members incorporated HCD within their yacht design. The champions' explanation and interpretation on HCD, its application during design, and comparison with the traditional design spiral, demonstrated his sound understanding of the HCD approach. This HCD champion's understanding of the HCD approach in maritime design can be graded as a Level 3 understanding according to the levels categorised in the rubric-A.

Experience as a peer leader in the team:
He appreciated the whole team effort in taking the HCD approach into account for the first time in this team design experience. He mentioned that his team members were easy to motivate to use the HCD approach by showing them the videos of the activities conducted on board the research vessel Bluefin.

> I participated [in the] stretcher exercise and store transfer exercise on board and realised how the design can [have a bad] effect on seafarers day-to-day operation and how it can risk their lives. When my team members saw those onboard videos during the introductory session, they got shocked. My team mates were well enthusiastic after the introductory lecture. There was not much motivation required to make my teammates [pay] attention to HCD.
>
> —champion of T4.

Furthermore, he stated the following methods used to facilitate and guide the team members to practice the HCD approach:

- Explained what he learnt during HCD scaffolding sessions
- Distributed the handouts given during the HCD scaffolding sessions to his team members

- Showed the useful videos and electronic pamphlets given during the HCD scaffolding sessions
- Showed the bad and good design examples

An example of his effort:

> My teammate, who was looking after the engine room layout design, had [a] few issues in selecting the size of the engine and other major machineries [while] considering operational maintenance tasks to be carried out as rapid, safe and effective. I showed him [a] few videos of small engine rooms and pictures of small engine spaces and how people work. Further, I have guided him to contact one chief engineer who I met during [the] HCD workshop.
>
> —champion of T4.

The champion explained his leadership experience below:

> Though I thought the HCD champion role would be an additional burden for me, finally it was a great leadership role to support and guide my team members to solve issues they cannot solve [on] their own. This would have been really difficult if I did not get [assistance] from the facilitators. Thus the framework used within this program was well organised.
>
> —champion of T4.

Motivation in practicing the HCD approach in the career:

He was passionate about his decision to become a yacht design engineer and he identified the yacht design field as one of the best arenas to practice the HCD approach. In addition, he mentioned that the designer must need care and skills to use the HCD approach to satisfy both the owner and the crew, due to the super luxury needs of the owner and HF requirements of the vessel crew.

> I will definitely try my best to practice HCD in future and motivate my future design teams as well.
>
> —champion of T4.

Feedback and suggestions on the scaffolding sessions:

The champion was satisfied with the scaffolding session schedule, delivery style and the guidance materials provided throughout. Furthermore, he liked the time slot used for the HCD scaffolding sessions – just before their weekly design project meetings – enabling him to effectively disseminate the knowledge to the team members. He further mentioned the effectiveness of short interactive sessions permitted him to actively converse with the facilitators. Finally, he mentioned a few suggestions to further improve the scaffolding sessions:

- Arrange workshop sessions to meet end-users more frequently

> It was extremely valuable for us to hear from real users about their tasks and operational issues they face so we can think how we can avoid them during [the] design stage. His feedback on our design solutions was very valuable and this meeting reduces the gap between users and designers. We realised that the designer is not a user of the ship after that workshop.
>
> —champion of T4.

- Utilise the time allocated for preparing lo-fi prototypes to plan other useful session like meeting end-users
- Discuss extra examples of HF issues onboard ships and examples of good designs to enable understanding of real-world applications of HCD
- Introduce more HF guidelines
- Arrange guest lectures conducted by seafarers to hear more on practical aspects of the ship operations

- Upload the scaffolding material and useful links to a shared folder where all students have direct access
- Include HF and HCD theoretical and practical sessions into the final year design project unit syllabus

5.5.2.4 (b) Questionnaire to team members

HCD understanding:

All five team members responded to the questionnaire. All of them explained HCD as a design approach, which will guide the designers to apply HF, ergonomic, and usability knowledge into the design process in order to make usable designs. They stated the following points to show their HCD understanding:

- HCD focuses on users of the design and their tasks
- Within the HCD approach, consideration must be given to user requirements, such as habitability, maintainability and workability to design any ship to support the people who work it
- HCD produces design solutions to make users happy, ensuring that the vessel is a pleasant place to work and rest
- HCD approach communicates with the end-users to get their feedback on designs throughout the design process
- The benefits that users would receive by considering the HCD approach, such as less working stress, reduced discomfort and tiredness, and minimal potential to error

While all team members defined and discussed the HCD approach, and the significance of designers' appreciation in HCD, they did not describe use of the principles of the HCD approach to develop a user-centred design through an iterative process. Thus, the HCD understanding of this group of team members of T4 can be categorised as a Level 2 according to the levels categorised in the rubric-A.

Motivation in practicing the HCD approach in the career:

Similar to the champion, all the team members expressed their motivation to practice the HCD approach in future designs.

Feedback and suggestions on the workshops and scaffolding material:

All five respondents highlighted the great value of the HF and HCD guidance materials, web links to electronic databases, and related videos, that they received through their HCD champion to stimulate their HCD knowledge. They acknowledged the exceptional value of the 'designers meet end-users' workshop. All of them requested more such sessions to be arranged, and guest lectures by seafarers to all design groups. However, they did not provide positive feedback on the CoU workshop. They asked that another useful session be planned instead of the CoU lo-fi workshop. However, they appreciated bringing end-user representatives in during the CoU workshop.

Opinions on HCD champion's facilitation and guidance:

All team members emphasised the champion's great facilitation and support given throughout the design project.

> It was really a group effort at the end but if our champion was not there we [would] miss the chance to learn and practice this valuable concept. This is new knowledge to all of us.
>
> —a team member of T4.

He described how he disseminated the HCD knowledge:

- Explained the phases of the HCD approach and methods learnt from scaffolding sessions
- Showed the location of electronic databases and useful videos
- Distributed the HF and HCD materials, related journal papers and pamphlets

5.5.2.4 (c) Design project report review

The owner of this design needed it for his personal use, accommodating 12 guests and six crewmembers. The design team treated all of them as primary users of their design. In order to provide luxuries to it, this design provided a full-beam large master suite, three large double guest cabins, a large twin bunk cabin suitable for accommodating four children, an exterior dining area on the bridge deck, an outdoor barbeque station, a wet-bar, internal bar and entertainment area, an indoor spa, and a fly bridge with dining area, to mention a few. Furthermore, the team exceeded the headroom height requirements suggested in some of the HF guidelines, such as the ABS (2013) and the MLC (2006), by providing a 2.7 metre deck to deck height, and a 2.4 metre deck to ceiling height throughout the accommodation deck, which is a good design consideration.

In addition, they provided two private double rooms for the captain and engineer, shared two-bunk cabins with attached bathroom facilities for the rest of the crew, and a private crew dining and entertainment area. Due to the size of the vessel and limited space available on the vessel, the design team had to locate the guest living area within the deck where machinery space, galley, and the crew mess and living areas were located. However, they had taken effort to separate the guest living area and the crew living area by placing the machinery room in between, which was not a usable design solution. They stated a few solutions, such as to select main engines, generators and shafts, which can reduce noise and vibration, and to use soundproofing materials (Megasorber Acoustic Foam) for noise reduction. Furthermore, the thickness of the internal bulkheads enclosing the large galley area was also increased to allow for insulation.

The design team provided an easy personal access routes for the laundry personnel, who takes care of supplying fresh linen and towels to the guest cabins, by placing the laundry within the guest accommodation area, as the laundry is likely to generate the highest demand when the 12 guests are aboard (see Figure 5.11). At the same time, they suggested to use noise protection insulation system to the bulkhead of the laundry to reduce the guest discomfort. During their design, they have made considerable effort to design all internal spaces with logistical and personal flow in mind to satisfy the primary user requirements. As an example, the chief engineer and cook were provided with quick and easy access to the engine room and galley respectively. In addition, the galley was also located as far aft of the forepeak bulkhead as possible to minimise the accelerations experienced in this area if crew were cooking whilst underway. The galley and cool/freezer stores are also located close to the internal staircase to try to minimise the distance that food stores would need to be transported when the yacht is replenished. Stores could also be loaded onto the vessel through the large fire emergency escape hatch located on the foredeck (see Figure 5.11). Furthermore, they have made a notable effort to take heating, cooling and ventilation requirements into account to maintain a high comfort level in cabins. Also, HF guidelines developed by ABS was followed to design stairs and landing spaces (ABS, 2014) of the vessel to safely carry an injured person on a stretcher and provide convenient transport of heavy machinery equipment.

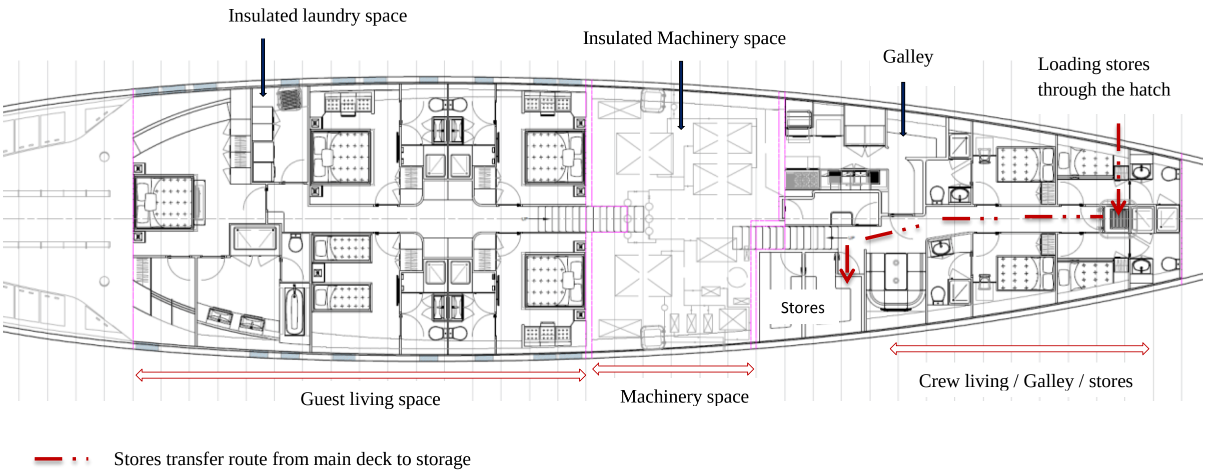


Figure 5.11: Design of guest living, machinery, and crew living space by design team T4 keeping user requirements in mind. (Reproduced with permission from design team)

In order to minimise the disturbances to the captain and the crew during night-time operations, especially from guests' entertainment events, they separated the entertainment area from the helm station with a bulkhead. Furthermore, this bulkhead provided noise insulation for the crew quarters allowing the crew members to be undisturbed during sleep. An internal tender garage at the stern of the vessel was designed to provide easy transfer of the guests and the crew. An extra watertight bulkhead is provided at the forward extent of the accommodation area so that if the hull is penetrated, this extra floodable compartment would increase the reserve buoyancy, focusing on the user survivability requirement when the vessel is operating in icy conditions. Though the team have not selected a specific bow thruster at this stage, the design included a location to fix a bow thruster to allow for greater manoeuvring performance in confined spaces during berthing operations. Due to the large size of the sail on board and the small number of crew, they identified the possible issues that crew might face during the operations. Therefore, they suggested in their design proposal to have hydraulic above-deck furlers for jib and code, while the main and mizzen utilised in-boom furling.

Further to above, they included a battery bank to support weak current equipment and they identified the tedious care and maintenance to be taken for traditional batteries. Therefore, to provide easy maintenance for the crew, they decided to include maintenance-free batteries, characterised by excellent reliability and free from special maintenance. Besides the above points, they mentioned the valuable feedback received from the end-user representative, who had yacht sailing experience, to improve their design. However, they justified trade-offs between user requirement and design solutions provided within the accommodation area. As a summary, though this team mentioned all primary users and the key tasks (see Table 5.7), they did not sufficiently describe each user's individual tasks and user responsibilities. In addition, they have not identified secondary users of their design. However, they identified frequencies for many tasks such as: the engine room crew's frequent access to the engine room; the demanding work within the laundry and guest areas; and the cook's frequent and demanding work in the galley, mess and entertainment areas.

Table 5.7: Context of use analysis of design team T4; Primary users and their key tasks.

Primary users	Tasks
Owner, 12 guests	Having parties and entertainment events with guests Spend the days' within a relaxing and peaceful environment with ultimate pleasure Sightseeing tours around the world
Crew - Captain, Chief Engineer, 4 support crew	Captain and supporting crew – Sail around the word, navigate and manoeuvre Chief Engineer – Daily work at engine room, maintenance work Cook – Cooking, stores handling (access to stores/galley) Supporting crew – demanding work at laundry station, sail operation

As a summary, his team have taken notable effort to design easy logistical and personal access routes for their users by linking tasks and user working areas which may lead to minimise the potential hazards. User requirements such as luxury, habitability, maintainability, accessibility and manoeuvrability were discussed and the trade-offs between user requirement and design solutions were justified. Accordingly, the application of the HCD approach during the design process of team T4 can be graded as Level 3 integration according to the rubric-B.

5.5.2.5 Team T5

5.5.2.5 (a) Interview with HCD champion

HCD understanding:

The champion identified the HCD approach to maritime design as a new approach that focuses on making the design usable for its users. She further explained the designers' responsibilities to 'design the problems out' at the initial design stage to avoid modifications in the detail design stage and the building stage. The following statement showed how she identified the HCD approach beneficial not only to ship design but also to other maritime designs such as their marina design.

> First I thought: why [do] we need HCD? We are not designing a ship, we are designing a marina. After I [was] introduced to real-world examples during the introductory lecture, I realised the HCD can be applied to any design. The users and tasks will be different from design to design.
> —champion of T5.

She further explained the benefits users may receive through the HCD approach as decreased stress and inconveniences, decreased potential to make errors, reduced hazards, and increased usability. She mentioned studying a similar type of designs from the HF perspective as a better approach to provide good design solutions to the users.

> I studied similar marina designs and found out that they did not give considerations to the walkway width. If the boat owners need to carry some heavy and big stuff, they need at least two people to handle. I noticed some walkway layout designs can create huge traffic [congestion].
> —champion of T5.

She further highlighted the designers' responsibilities to show their designs to the end-users and obtain their feedback to improve the design. As she explained, HCD is an iterative process and more usable designs will be a result of many iterations of the design with user-based evaluations. The champion's explanation and clarification on the HCD approach, its application, benefits, and the importance of designers' appreciation of HCD, demonstrated her sound understanding of the HCD approach to maritime design. Hence the HCD understanding of this champions can be graded as a Level 3 understanding according to the levels categorised in the rubric-A.

Experience as a peer leader in the team:
She expressed difficulties faced during her peer leadership. According to her following explanation, her team members did not believe in HCD.

> My team mates and I always work together, friendly. However, when it [came] to HCD application, I was doing it alone. They considered HCD as mostly common sense and they basically did not want to do anything out of scope of the project. They just wanted to complete the clients' requirements. Since [the] client [had] not specified anything related to HCD, they always think that [it] is not at all [a] priority. They have not seen this component in the design project unit syllabus [either].
> —champion of T5.

She expressed her effort taken to make them realise the importance of the HCD approach. She distributed the reading materials and useful videos, and explained what she learnt after every scaffolding session. However, the team members have not put any effort to consider the user requirements when they were progressing in their responsible sections of the design. Therefore HF integration into the design became her responsibility.

Motivation in practicing the HCD approach in the career:
She expressed her willingness to practice the HCD approach during her career. However, she highlighted the following points, which are possibly affecting every designer's willingness to practice the HCD approach in the design teams:

- Team members' level of appreciation of the importance of HCD approach
- Design company's level of motivation to accomplish something which is relatively new to the maritime domain.

Feedback and suggestions on the scaffolding sessions:
The champion was satisfied with the total scaffolding program. She was happy with the short interactive sessions rather than delivering long lecture sessions. The following points were highlighted for improvement to the next year's scaffolding sessions and to motivate those who do not really believe in this approach:

- Add HF and HCD theoretical sessions and practical sessions into the final year design project unit syllabus
- Talk to design project clients and request they add HCD to the design briefs
- Arrange more ship visits
- Arrange more workshop sessions to meet end-users and make sure they are related to the design project theme
- Arrange guest lectures from different end-user representatives to cover different areas, such as offshore

<u>5.5.2.5 (b) Questionnaire to team members</u>

HCD understanding:
Three out of four members provided valid responses to the questionnaire. They described that the HCD approach was not included in the design project unit syllabus and thus, it was not necessary for them to use it during the design. This is identified as completely incorrect understanding of HCD.

Hence, their HCD understanding level can be graded as a Level 0 understanding according to the rubric-A.

Motivation in practicing the HCD approach in the career:
None of them indicated their motivation to practice the HCD approach in their career.

Feedback and suggestions on the workshops and scaffolding material:
There was no feedback or suggestions to improve the workshops and scaffolding materials.

Opinions on HCD champion's facilitation and guidance:
Their responses were very short and mentioned the champion's passion in integrating HCD into their design project. Two respondents specified the champion's effort to disseminate the HCD knowledge she gained during scaffolding sessions and the distribution of the HCD materials.

5.5.2.5 (c) Design project report review
The main scope of this design project is identified as redesigning the existing marina in order to integrate of wave energy converters and floating breakwater. The design process identified following personnel as the primary users and listed the tasks/activities of the design be used to perform or support:

- Boat owners – berth the vessel, access the vessel, vessel mooring, deploy rigid hull inflatable boats
- Guests of boat owners – access the vessel
- Marina visitors – walking through the walkways to see the beauty of the place, attending sailing training courses at marina
- Maintenance personnel – install and maintain pontoon structure, maintain wave energy converter devices

The design provided adequate access from the shore to the marina berths. The design included a two-metre wide bridge that allowed the bringing of wide trolleys towed by vehicles. In addition, the width of the main walkways to the vessels was given as 2.75 metres, allowing boat owners, guests and visitors adequate space to carry provisions, equipment and any necessary gear. Anti-slipping decking material was selected to minimise the potential for slips, trips and falls. The design further identified the need for lifting a vessel into and out of the marina and therefore provided a sling lift within the marina. Furthermore, this design provided a small slipway for deploying rigid hull inflatable boats, considering the trainees who attend courses or private leisure activities. The marina layout included a fuel station to satisfy the user requirements, and the location was selected based on three factors: it needed to be accessible to all vessel sizes; the berthing area for refuelling vessels needed to be well sheltered from wave disturbance; and the location must not block or be situated along routes to the land for safety. In this design, each walkway was provided with its own shore connection to minimise traffic flow and bottle necks at junctions between walkways. Firefighting reels were located with a 30 metre radius operation within 30 metres of each other and the berths.

This design report mentioned that the design received valuable feedback from the end-user representative. Ultimately, this design report provided recommendations, as follows, to the project client to consider making a usable design and to continue maintaining the user satisfaction.

- The wave and wake attenuator screening device, which is a floating device supported by two mooring piles, should not be used for mooring vessels. If a vessel is moored to the wave screen device, it will present a risk to damaging either the device or the vessel's hull. Therefore, appropriate signage along the wave screen must be provided.
- If marina management allows marina users to access the wave screen walkways, it is recommended to provide suitable hand railings.
- Accessing the Wave Energy Converter (WEC) unit for maintenance purposes would require at least one diver and a small work boat with a derrick. The WEC unit and its cradle must be secured to the derrick by the diver, the air hose connection between the WEC and the generator system closed on both sides and separated, and then the bolted fastenings between the cradle and the heave frame must be undone by the diver. The WEC and its cradle can then be lifted out by the work boat for maintenance or replacement.
- With the new electrical grid system, it is essential that all personnel be familiar with the new layout to ensure controllability.

Upon reviewing this design report, it can be identified that the report exhibited a notable effort to analyse the CoU, though it did not sufficiently identify each user's individual tasks and user responsibilities. The design report did not include solutions for the safety and security of the marina, such as providing self-locking gates for each main walkway, and maintaining a security camera system in operation throughout the marina. However, the effort to consider user requirements such as accessibility, maintainability, safety, and survivability was noteworthy. In addition, the effort was notable to design user-friendly logistical and personal access routes for the users by linking tasks and user working areas. Accordingly, application of the HCD approach during the design process can be graded as Level 3 integration based on the rubric-B.

5.5.2.6 Team T6

5.5.2.6 (a) Interview with HCD champion

HCD understanding:

This champion said that that the maritime industry is becoming increasingly aware of the value of the HCD approach in the design process that focuses on making designs usable for its users. He stated the ISO (2010) requirements and recommendations for HCD and described the five essential phases of HCD. In addition, he recognised the value of the designers' clear understanding of maritime HF and HCD to produce a usable design. Further to that, he stated the importance of CoU analysis to produce better design solutions. Subsequently, he specified the complexity of the user and task analysis for very complex systems like ships and offshore facilities. However, he mentioned that if the whole design team were committed to applying the HCD approach into the design, such complex systems would also become happy homes to its users. The following is an example where he identified the consequence of design evaluation with end-users and ergonomic software.

> I realised how important [it was] to consult end-users to evaluate the design. We designers do not have any idea of operational issues, how they operate, who operate[s]. If you can use software like Human-CAD, where you can place a mannequin and check the reachability and operability, how useful it is to evaluate your design.
>
> —champion of T6.

However, he did not discuss challenges designers may face during the HCD approach and how those can impact on the final design. In general, the champion's explanation and clarification on the HCD approach, its application, benefits, and consequence of designers' appreciation of HCD, demonstrated his sound understanding on the HCD approach to maritime design. Thus, according to the levels categorised in the rubric-A, the HCD understanding of this champion can be graded as Level 3.

Experience as a peer leader in the team:
The whole team contribution in increasing the inclusion of HF consideration into their design was highlighted by the champion, who also mentioned how he guided and facilitated his team members throughout the project period in practicing the HCD approach:

- Distributed handouts to the team members received during scaffolding sessions
- Explained what he learnt during HCD scaffolding sessions to the team members
- Showed the videos and electronic pamphlets
- Motivated the team members to consult end-user representatives
- Showed the bad and good design examples

He mentioned that the introductory lecture conducted with real examples motivated all of his team members to pay attention to the importance of HF consideration in maritime design.

Motivation in practicing the HCD approach in the career:
He was enthusiastic to apply the HF and HCD knowledge, acquired during the scaffolding sessions, during his career to design usable marine and offshore designs. However, he identified the need of gaining more comprehensive knowledge in maritime HF and HCD. Furthermore, he stated the competence he gained through the champion experience to influence his future design team members in integrating the HCD approach during design.

Feedback and suggestions on the scaffolding sessions:
The champion was satisfied with the scaffolding program. He stated that the weekly scaffoldings sessions were arranged at a perfect time slot – just before the weekly design project team meetings – enabling him to effectively disseminate the knowledge to the team members. He suggested adding HCD theoretical sessions and practical sessions permanently into the final year design project unit.

5.5.2.6 (b) Questionnaire to team members
HCD understanding:
All three design team members responded with valid answers to the questionnaire. All of them identified the HCD approach as a valuable design approach that can make systems usable by taking the user requirements and the user capabilities into account. They explained the CoU analysis as the key to find out users of the design, their tasks and the operating environment. They stated the benefits that crews would receive by incorporating the HCD approach, such as reduced crew/guests discomfort, stress, fatigue, and increased efficiency and effectiveness while performing tasks. Though all of them defined and discussed the HCD approach and its importance at an acceptable level, they did not discuss the use of the principles of the HCD approach to develop a user-centred design through an iterative process. Hence, based on their responses, the HCD understanding of this group of team members of T6 can be graded as a Level 2 understanding according to the rubric-A.

Motivation in practicing the HCD approach in the career:
All respondents gave short answers and highlighted their readiness to apply the HF and HCD knowledge acquired during this year in their career.

Feedback and suggestions on the workshops and scaffolding material:
All respondents appreciated the HF and HCD learning materials they received through their HCD champion. They stated the exceptional value of the 'designers meet end-users' workshop, where they received valuable feedback and suggestions on their design for improvement. However, they highlighted the significance of consulting a seafarer who has similar experience related to the design project scope.

> [The] user meeting session was exceptionally valuable for our team. It would be much more valuable if the [user representative] had similar background like [on a] research vessel with launching and recovery system operation.
> —a team member of T6.

None of the respondents provided positive feedback on the CoU workshop. They gave a few suggestions:

- Arrange more 'designers meet end-users' sessions rather than having a CoU workshop
- Invite seafarers with offshore experience to have more impact on marine and offshore designs
- Upload the scaffolding material and useful links to a shared folder where all students have direct access

Opinions on HCD champion's facilitation and guidance:
Both respondents identified the HCD champion as a member in their team having more understanding on maritime HF and HCD. According to their explanation, they talked to him whenever they needed support in HF integration. In addition, they appreciated their team champion's effective dissemination and support given throughout the year to learn and apply HCD into their design.

<u>5.5.2.6 (c) Design project report review</u>
This team, who designed a LARS for an AUV, were clear in the beginning that the client's requirement was to design a modular 20-foot containerised LARS to launch AUVs up to 10 metres long by 0.75 metres diameter and a maximum of 2.5 tonne weight. Additionally, they had taken a notable effort to analyse the CoU of this design in order to produce better design solutions. They identified LARS operators; data acquisition people, such as researchers and scientists; maintenance people; and lifting operators as their primary users. The summary of their CoU analysis can be tabulated as in Table 5.8.

Based on their CoU analysis, the design team identified that their users needed to have a LARS design that could operate in extreme temperature conditions with a minimum possible impact of health, safety and comfort of all personnel involved. Therefore, they did a comparison between four design concepts to find the best design for the selected context. Finally, they identified an extending boom design concept to develop their design to satisfy the user requirements (see Figure 5.12).

Table 5.8: Context of use analysis of design team T6; Users, operating conditions and key tasks.

Users	LARS operating crew, data acquisition people, maintenance people, lifting operators of the module, and the vessel that will use this design
Operating area	Antarctic regions
Expected vessels of opportunity	Aurora Australis, RV Investigator, MV Bluefin, RV Polarstern
Operating conditions	Extreme temperature conditions and regular high winds Antarctica – generally around 0°C Winter – temperatures drop to between -10°C and -30°C. This temperature continues to decrease further from the coastline Lowest temperature ever recorded was -89.2°C Extreme swells and seas of 12m can be expected to occur in all months
Key tasks of the design	AUV deployment and recovery through ice Data acquisition Transport from vessel to vessel

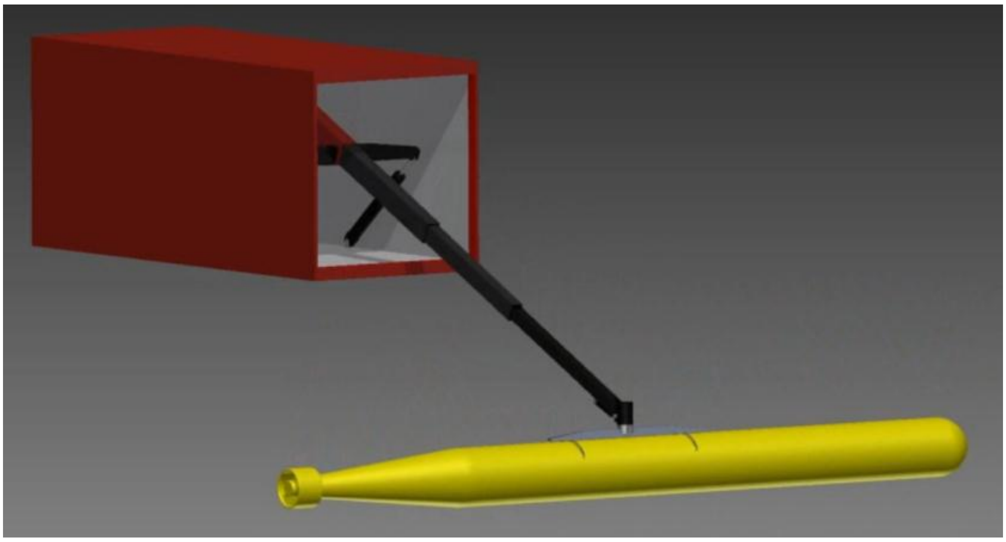


Figure 5.12: Extending boom design concept is identified by design team T6 to satisfy their user and operational requirements. (Picture used with consent)

Furthermore, they identified the following factors of the design as usable design solutions:

- Ease of transportability of this design concept due to fitting inside a standard-sized shipping container
- Ease of storage inside the container and already in a position to be lifted
- Provide sheltered place for operation, maintenance, battery charging and data acquisition
- Pivoting boom and cradle system design to minimise the potential risk to the operating crew, vessel and the AUV due to relative motion between the AUV and parent vessel

The design team figured out the requirement of having one engineer and two crewmembers inside the container supervising the whole process, and guiding the AUV as it is winched up in the boom head cradle prior to launching. Also, four other staff members, two on either side of outside the container, should support by guiding the process. They mentioned the valuable feedback received through the ‘designers meet end-users’ session to identify the number of engineers and crew members available to perform launching and recovery operations. They evaluated their design using Human CAD ergonomic evaluation software by placing manikins inside the container (see Figure 5.13). As a result, they concluded that the space inside the container would be sufficient for three people to stand during the launching and recovery operation. However, they recommended designing a custom made container box to provide more working space for the users during launch, recovery and maintenance, hence reducing the potential hazards while working.

As a summary, this design team made a notable effort to analyse the CoU, though they missed their secondary users, such as transporters of the module. Their design solutions were well supporting of its primary users to conduct the operation and maintenance. The design demonstrated not only the use of user feedback, but also the utilisation of the additional analysis method – the Human CAD ergonomic evaluation tool – to re-evaluate the design, as introduced during the scaffolding sessions. Accordingly, application of the HCD approach during the design process of this team can be graded as Level 3 according to the rubric-B.

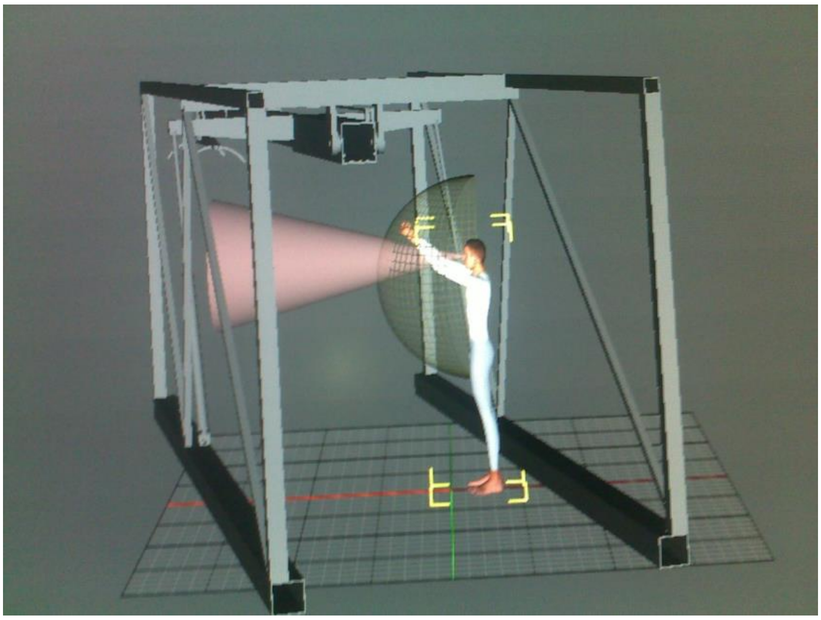


Figure 5.13: Design team T6 evaluated the design using HF evaluation software; HumanCAD®. (Picture used with consent)

5.5.1.7 Team T7

5.5.2.7 (a) Interview with HCD champion

HCD understanding:

The champion identified the importance of the HCD approach within maritime designs in order to design ships or offshore structures suited for its users. He explained the five essential stages of the HCD process and the user requirements such as habitability and maintainability. Further to this, he explained the personal experience gained during his industry training and connected it with the importance of designing usable ships.

> During my training in dry-docks, I saw how difficult [it could be] to reach some valves. [An] engineer had to stand on something to reach those. Not only that, I saw how difficult [it was] to load stores and provisions to dry stores when I was on board our research vessel. Including user requirements when we design ships is very important. The HCD approach can guide us to do so.
>
> —champion of T7.

Though he discussed the HCD approach and its importance, he failed to describe the use of principles of the HCD approach to develop a user-centred design through an iterative process. Hence, the champion's understanding of the HCD approach in maritime design can be graded as a Level 2 understanding according to the rubric-A.

Experience as a peer leader in the team:
This team champion's feedback on his experience as a peer leader was not positive. However, he did not want to explain possible reasons for his unpleasant experience.

> My experience was not good in motivating my team mates. I tried my best to pass the message. They ignored me.
> —champion of T7.

Motivation in practicing the HCD approach in the career:
He was keen to apply the HF and HCD knowledge acquired during his study to produce better designs in the future. He further stated the value of the design team's support to become successful in the HCD approach.

> If you do not have good support from your team, then it will be nearly impossible to practice HCD.
> —champion of T7.

Feedback and suggestions on the scaffolding sessions:
He appreciated the motivation, guidance and facilitation received through scaffolding sessions throughout the final year. His suggestions included:

- Arrange more workshop sessions to meet end-users
- Arrange visits to different types of vessels and allow students to talk to seafarers
- Include maritime HF, HCD and practical sessions into design project unit syllabus

5.5.2.7 (b) Questionnaire to team members
HCD understanding:
Three members out of four responded to the questionnaire. All three respondents mentioned their unawareness of maritime HCD. Hence, their understanding of the HCD approach was lacking (Level 0) according to the levels categorised in the rubric-A.

Motivation in practicing the HCD approach in the career:
No one indicated their motivation to practice the HCD approach in their career.

Feedback and suggestions on the workshops and scaffolding material:
There was no feedback or suggestions provided by the team members.

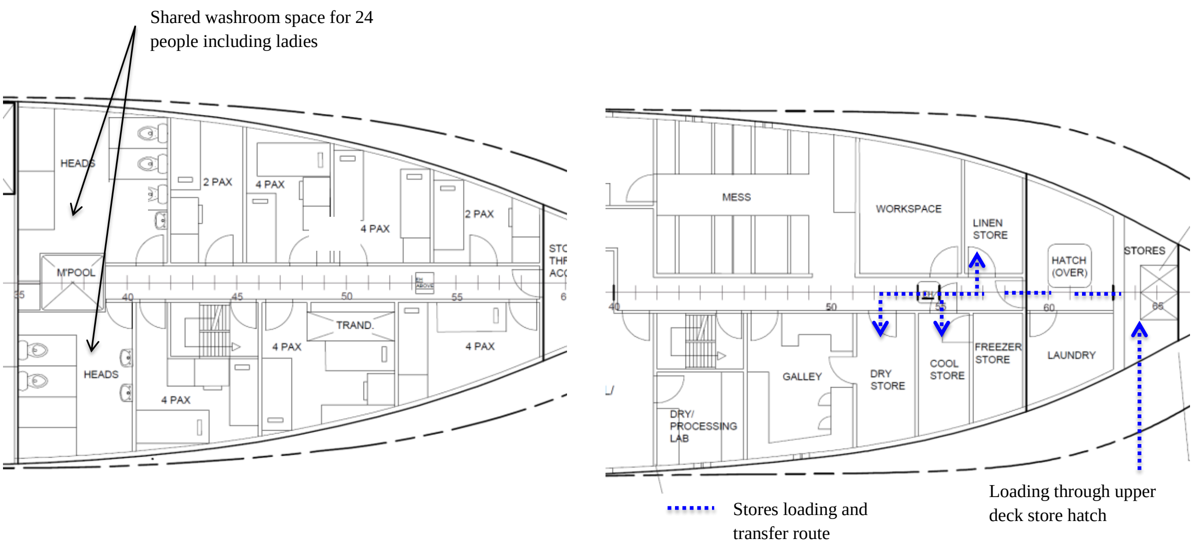
Opinions on HCD champion's facilitation and guidance:
All three respondents stated the champion's inadequate dissemination of the knowledge he gained through the HCD scaffolding sessions.

5.5.2.7 (c) Design project report review
The task of this design team was to redesign AMC's research vessel to fulfil a large range of roles in research, training, and offshore support. The team identified the tasks that would be performed by the vessel, such as conducting oceanographic surveys, mapping seabeds, conducting training for seafaring

students, pipeline surveying, launching and recovering of ROVs/AUVs, and fishing. Even though they identified the activities expected from the vessel, they did not mention who would be performing these tasks, how many operators would be needed, or how many researchers and students would be using this vessel.

This vessel design currently suffers from a number of HF issues associated with its accommodation layout, machinery space layout, control station layout, accessibility of demanding spaces, logistical and personal access routes, stairways, walkways, headroom, and logistics according to the findings from the visit to Bluefin (Abeysiriwardhane et al., 2014). However, this design team did not mention these issues at all within their proposal design. The effort they had taken to provide solutions for those issues was the bare minimum. The accommodation spaces allocated for 24 passengers, including researchers, lecturers and students (female and male), were only provided with two shared bathroom spaces (see Figure 5.14[a]).

However, the design provided solutions for the issues users are facing during provision loading and transferring. A storage hatch was provided on the forecastle deck that directly loads stores into a storage compartment using a forward deck crane, and can then be transferred to small dry stores, cool stores, freezer stores and linen stores (see Figure 5.14[b]). Quick and easy access to dry, cold and freezer stores from the galley and mess was another design solution provided to make seafarers work easy. Nevertheless, the garbage disposal station was located on the next deck level to the mess deck and the crew would have to use the stairs to access the garbage area even in the harsh weather conditions. Upon reviewing this design report, it can be identified that this team exhibited a slight effort to incorporate user requirements within their design. Furthermore, this design did not mention any user-based evaluation to pursue more user-friendly design and all the latter points lead them to be categorised under Level 0 according to the levels described in the rubric-B.



5.14(a) 5.14(b)

Figure 5.14: Successful and unsuccessful design solutions by design team T7.
(a) Accommodation and sanitary layout design for passengers, (b) Design of the locations of galley, mess and stores, and access routes keeping user needs in mind. (Reproduced with permission from the design team)

5.5.2.8 Team T8

5.5.2.8 (a) Interview with HCD champion

HCD understanding:

The champion expressed her understanding of the HCD approach as: designing ships, offshore facilities or other maritime designs to be fit for its users. She explained that if the design does not satisfying the user requirements, then the users are not happy to work. She stated the ISO (2010) standard as a guide for designers to produce usable designs. She further explained the five essential phases of the HCD approach according to the ISO guidelines. The champion also explained difficulties that designers may face during CoU analysis for complex designs like submarines.

> [The] submarine is a very complex design, and there are approximately eight officers, 11 senior sailors and 41 junior sailors [to] accommodate and work. We, as designers, were able to identify major tasks but not individual. Without having any experience in [a] submarine this is very challenging, I recognised. If we met up with [a] submariner before we commence[d] the project, that could have been great and it could have [had] a great impact on the final design.
>
> —champion of T8.

Interestingly, she discussed the trade-off studies the designers should perform before producing the final design solution.

> Once we identified issues and solutions, we must consider [a] trade-off between design options and user needs. Issues must be considered in the trade-off between design options.
>
> —champion of T8.

Her explanation included the benefits that users may receive through the HCD approach as decreased stress, inconveniences, and the potential to make errors, especially within congested spaces like submarines. In addition, she highlighted the use of HF guidance documents that currently exists in the literature, such as the ABS (2003a) and the MLC (2006). She took one example application of HCD from her design project to explain the use of the principles of the HCD approach.

> Food and beverages [had to be carried via] the access ladders from the galley to the recreational spaces on past submarines. We provide [a] dumbwaiter, [which] can reduce [the] potential incidences of trips, slips and falls, and indeed it would provide easy [logistical and personal] access routes for galley and mess crew.
>
> —champion of T8.

Her explanation included challenges in the HCD design process, such as convincing the client of the value of the HCD approach, convincing team members to follow the HCD approach, and analysing the CoU iteratively within a limited time frame. The champion's explanation and clarification on the HCD approach, its application, benefits, and consequence of designers' appreciation in HCD demonstrated her sound understanding of the HCD approach to maritime design. In addition, she discussed the challenges that designers face during HCD integration and its impact on the final design. Hence the HCD understanding of this champions can be categorised as a Level 4 understanding according to the levels categorised in the rubric-A.

Experience as a peer leader in the team:

Firstly, she stated the valuable experience she gained through her champion role, which provided guidance and support to her team members in acquiring new knowledge and skills. She recognised their final design proposal as a result of a team effort because all team members appreciated the HCD concept from the beginning of the project. Furthermore, she mentioned the motivation her team members received from the first introductory lecture delivered to all students.

> First they thought HCD could not be applied in submarine design [because it] is recognised as conventional design. However, they [were] encouraged after the introductory lecture we all received in the beginning. They all wanted to become champions. Therefore not much motivation required; however, when they were struggling at any situation, I supported them.
>
> —champion of T8.

After every scaffolding session she would explain the topics to her team and distribute the reading materials and useful links, such as library e-book links, electronic database links and HF guidelines.

Motivation in practicing the HCD approach in the career:
She was prepared to apply the HF and HCD knowledge, acquired during her study, in the future to produce better designs, and appreciated the opportunity as given below in her own words.

> I am lucky, I got this opportunity to attend [these] scaffolding sessions. Otherwise it would have been impossible [to] change our technical mind-sets.
>
> —champion of T8.

Feedback and suggestions on the scaffolding sessions:
She appreciated the motivation, guidance and facilitation received throughout the scaffolding sessions. She suggested the following points to further improve the delivery of the scaffolding sessions:

- Discuss examples from special designs such as submarines and offshore wind farms
- Include HF and HCD theoretical sessions and practical sessions into the final year design project unit syllabus
- Assign an end-user to engage with the team throughout the design process or arrange more workshop sessions to meet end-users

> It was valuable and [an] honour for me and my team mates to have a discussion with a Submariner and that was the most valuable hour we [spent] during [the] design project time. Hearing from real users about their tasks and operational issues was incredible.
>
> —champion of T8.

<u>5.5.2.8 (b) Questionnaire to team members</u>

HCD understanding:
All four team members responded to the questionnaire. All of them identified the HCD approach as a valuable design driver that can make systems usable by taking the user requirements and the user capabilities into account. Five essential steps were explained by all four respondents. They mentioned the benefits seafarers may receive through the HCD approach, such as reduced stress and fatigue during work, increased comfort, and minimised potential hazards due to proper ergonomic consideration in terms of reach, space and access. Though all of them defined and discussed the HCD approach and its importance acceptably, they did not summarise the use of the principles of the HCD approach to develop a user-centred design through an iterative process. Hence, the HCD understanding of this group of team members of T8 can be graded as a Level 2 understanding according to the rubric-A.

Motivation in practicing the HCD approach in the career:
All team members highlighted their motivation to continue the use of the HCD approach in their future designs, as they identified its benefits to the end-users in order to perform their jobs easily, safely and effectively.

Feedback and suggestions on the workshops and scaffolding material:
All team members stated the exceptional value of the 'designers meet end-users' workshop, where they received valuable feedback and suggestions on their design for vast improvement. All of them appreciated the HF and HCD learning materials they received through the HCD champion. They all suggested planning other useful sessions instead of the lo-fi prototyping workshop. In addition, all of them suggested including HCD into the design project unit syllabus. There were no other suggestions provided by the team members to improve the scaffolding materials.

Opinions on HCD champion's facilitation and guidance:
All four team members appreciated the champion's effort to disseminate the knowledge she gained from the HCD scaffolding sessions effectively.

5.5.1.8 (c) Design project report review
Through client specification, this design team was clear about the requirement of this diesel submarine with the ability to undertake anti-surface and anti-submarine warfare including Special Forces insertion and recovery. Furthermore, it had to utilise current commercial and military technologies and must comply with the standards and expectations as given by the Royal Australian Navy. This design team took HCD as a primary design driver and had a separate chapter in the report to explain HCD consideration. The design team identified the primary users of this design as Australian Navy seafarers of approximately eight officers, 11 senior sailors, and 41 junior sailors. The range would allow the vessel to be operated anywhere from the Middle East, across the Indian Ocean, through South East Asia and across the Pacific, while reaching as far north as the Arctic Circle and as far south as Antarctica.

Though a conventional submarine design is cramped in terms of accommodation and working space requirements, this design team took a great effort to utilise their space to provide good comfort and easy working environment for the users. To begin with, they provided the maximum possible space for sleeping, dining, recreation, bathroom facilities and dry stores. They mentioned how helpful the HCD workshop sessions and user feedback session was to include the user needs into the design process.

> The design of a submarine is unique, as the operational requirements often impose upon the requirements for living spaces on board, and the environment can be cramped and hard to navigate. Through discussion with past and current submariners, the design team was able to take user feedback into account and hence create user-friendly design options.
> —submarine design team (T8).

Even though a laundry is not a standard inclusion on conventional submarines, this design team decided to include a small laundry compartment on board considering crews stay at sea for sisxty days, based on the experienced submariners' feedback. This laundry compartment was located away from accommodation and recreational spaces to isolate noise. To further reduce inconveniences on board the use of sliding doors for compartments was chosen, thereby reducing the required space and injuries that could occur by a door swinging into narrow passageways. On conventional submarines, food and beverages need to be carried up the access ladders from the galley to the recreational spaces. This design provided a dumbwaiter that can reduce potential incidences of trips, slips, and falls, and indeed it would ease the tasks of the galley and mess crew.

In addition, this design provided a small kitchenette in the passageway between the Officer and Senior Sailor recreational spaces that would contain a coffee machine, microwave, small dishwasher and sink for convenience. This design decision was also made based on the feedback they received from the experienced submariner during the 'designers meet end-users' workshop session. A vertical multi-purpose hatch, located just aft of the sail, was provided to load cold, dry, and engine room stores, reducing the distance required to move and locate stores. The forward emergency hatch could be used to load other requirements for the forward control and ship's office (see Figure 5.15).

During the discussion with the experienced submariner, they recognised the Chief Officer as the key officer to be called in an emergency or for access to the small arms stowage. Thus the Chief Officer should have easy access to the control room of the submarine. Therefore, the Chief Officer's cabin was placed directly aft of the control room. There is adequate space provided for the ship's office and forward control room for 12 consoles on the port and starboard side, a central control desk for periscopes, and a chart table located on the central axis. Consideration for deck height can be taken as prime design limitation of the pressure hulls. Nonetheless, all compartments within this design were provided with 2.4 metre deck to ceiling height, and considerable space is given for the cable trays and piping.

The design team changed their engine room layout design from a conventional submarine to provide better maintainability and a good working environment for those who would work there. They found that if three generators were placed parallel across the vessel, due to the width of the generators, the arrangement would not provide sufficient room between the generators for maintenance access or for ventilation. Hence, they placed two on the starboard side and one on the port side (see Figure 5.15). Accordingly, the engine room layout provided adequate space for the other equipment that needed to be situated in the engine room, such as the Stirling engines, machinery workshop and HVAC equipment. Due to the proper utilisation of the machinery space, they were able to provide sufficient space for the laundry room.

A vertical multi-purpose space, and a cylindrical chamber were designed to support Special Forces insertion and recovery operations. Special Forces could enter the cylindrical chamber wearing all the diving gear, and be able to swim out and return. With given consideration to the survivability and emergency routes, the design team provided two rescue hatches: one accessed through the aft (auxiliary) control room, and the other accessed through the forward main control room. These locations were chosen as they were considered the most accessible from any compartment on the vessel.

As a summary, this team incorporated primary users, their key tasks and operational environment as a basis for design decisions, yet they did not sufficiently identify each user's individual tasks and user responsibilities. In addition, they have not identified secondary users of their design, such as submarine support ships and submarine rescue vessels. However, they identified frequencies for major tasks such as the engineers' access to the engine room workshop and engine machinery room, and the galley and mess crews' frequent and demanding work in the galley and delivering food. They have taken noteworthy effort to design user-friendly logistical and personal access routes for their users by linking tasks and user working areas. User requirements such as habitability, maintainability and accessibility were adequately discussed. Accordingly, application of the HCD approach during the design process of this team can be graded as Level 3 integration based on the rubric-B.

> We, as a team, consider[ed] HCD in our design process for the first time in our undergraduate period, and [it was] really valuable knowledge we gained by practicing it. We highly appreciate the effort taken by [the] HF Research Team, AMC, to deliver this knowledge.
>
> —submarine design group (T8).

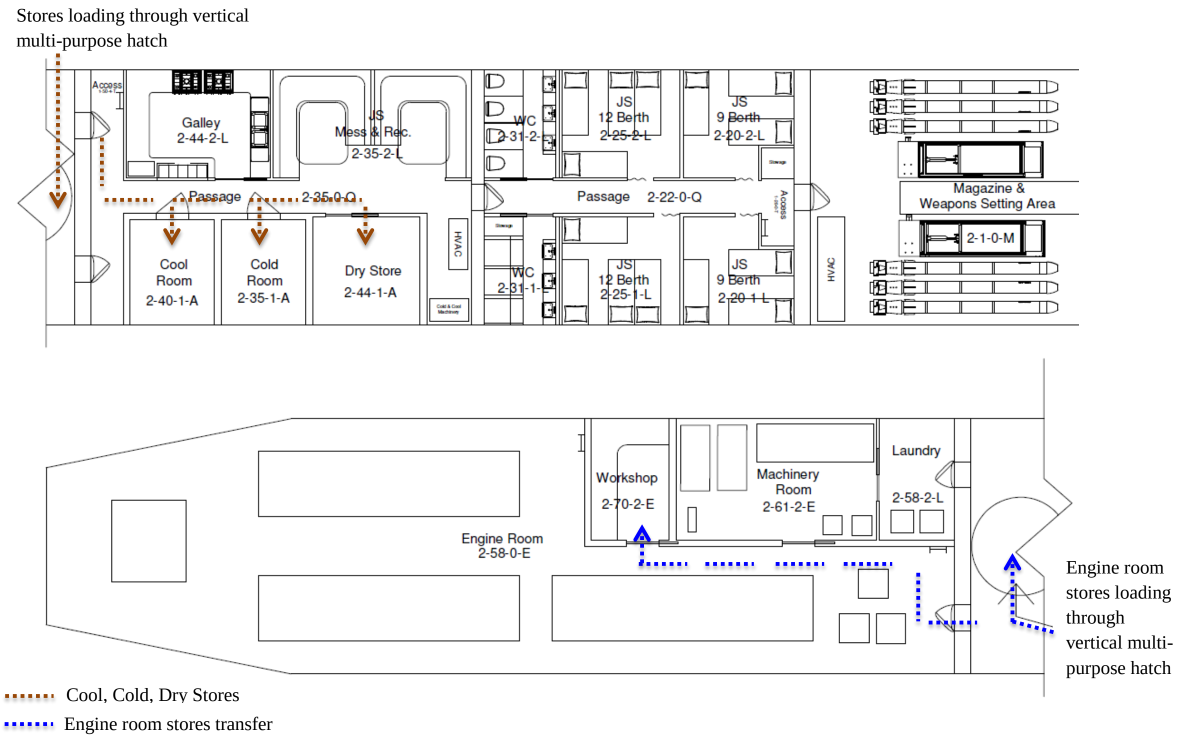


Figure 5.15: Design of stores transfer routes by design team T8 considering users requirements. (Reproduced with permission from the design team)

5.5.3 Results summary

5.5.3.1 HCD understanding of champions and team members

As illustrated in Figure 5.16, two out of eight HCD champions (T3 and T8) exhibit excellent understanding (level 4) of the HCD approach. Their accurate explanations on the definition, processes, iterative nature, benefits and methods followed within the HCD approach exhibit the sound theoretical knowledge that they possess after the scaffolding sessions. Furthermore, they demonstrate the influence of the user perspectives on an innovative design that can be labelled as an HCD. They noted the challenges that designers face during the HCD approach and discuss the impact of those on the final design. Furthermore, they explain suggestions to overcome those challenges. This demonstrates their well-established understanding on the application of HCD within the design process. Five champions (T1, T2, T4, T5 and T6) exhibit a sound understanding (level 3) of the HCD approach. These champions also demonstrate sound theoretical knowledge acquired during the scaffolding sessions. However, they are lacking when explaining challenges within the HCD approach, limitations and suggestions whereby they only abstract the use of the principles of the HCD approach to develop a user-centred design through an iterative process. The champion who represented team seven was able to provide a general idea about the HCD approach with his definition. Nevertheless, he lacks knowledge on the use of the HCD approach to develop usable designs thus reaches level 2.

Having the peer guidance according to the teaching framework, members of five design teams (T1, T2, T4, T6 and T8) exhibit a moderate level of understanding (level 2) at the end of their design project unit. It was disappointing to see that, after making such an effort, the members from the other three teams (T3, T5 and T7) had nothing to do with HCD based on their questionnaire findings leaving them in level 0 of the rubric-A. They still consider HCD as 'common sense' and do not want to integrate it into the design process due to the nonexistence of the HCD requirements within the design project unit syllabus or client's specifications. However, as found in the results, all the participants who answered the questionnaire – including the HCD champions and their team members – heard about the HCD approach for the first time in their undergraduate studies.

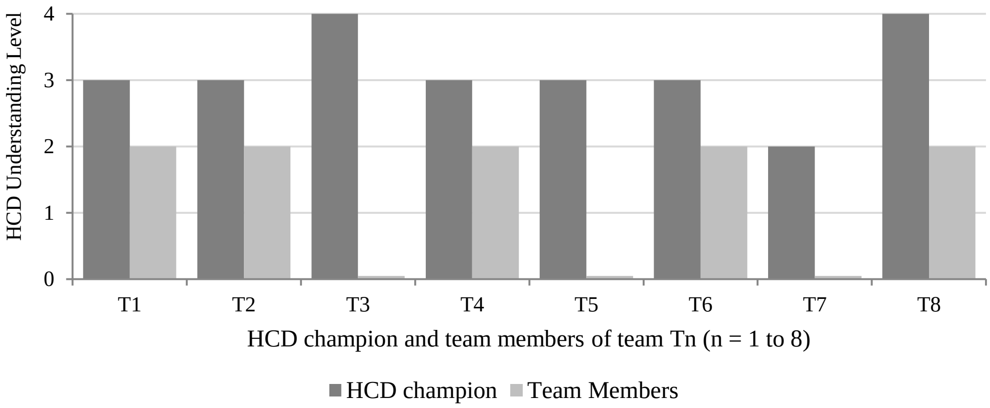


Figure 5.16: The HCD understanding level of champions and team members.
Level 0 – Lacks understanding, Level 1 – Basic understanding, Level 2 – Moderate understanding, Level 3 – Sound understanding, Level 4 – Excellent understanding

5.5.3.2 Peer leader experience of HCD champions and team members' feedback on HCD champions' facilitation and guidance

HCD champions from five teams (T1, T2, T4, T6 and T8) are satisfy with their role and the responsibilities they were given to support and guide their team members to acquire HCD knowledge. In addition, all of them highlight their team members' appreciation, and support given throughout the design process to ease the HCD integration into the design. Likewise, all of their team members' impressions are positive on the champions' facilitation and guidance in applying the HCD approach during the design project. Furthermore, they highlight the champions' enthusiasm in integrating the HCD approach and appreciate their way of disseminating HCD knowledge and the distribution of the guidance materials.

Yet, three other champions (T3, T5 and T7) provide negative feedback on their experience. Two of them (T3 and T5) give the following causes they believe made their team members disregard the HCD approach:

- Their perspective on HF and HCD as common sense
- Their perspective on HCD as an additional burden since it was not included in the design project unit syllabus or client's specification

However, the team members from T3 and T5 do not resist their champions integrating the HCD approach into the design projects. On the contrary, the champion of T7 receives negative feedback on his work from his team members. They point out the champion's inadequate dissemination of the knowledge he gained through the HCD scaffolding sessions.

5.5.3.3 Integration of the HCD approach into design projects

As illustrated in Figure 5.17, seven design projects exhibit an adequate level of HCD integration (level 3) into their designs. They show their commitment to incorporate primary users, task-related considerations and analysis of operational scenarios as a basis for their design decisions. Furthermore, they take a notable effort to link the users with the tasks and their frequencies. They consider the end-user feedback to pursue user-friendly designs via the iterative process, while justifying the trade-offs between the user requirements and the design solutions. In addition, they demonstrate the use of HF guidelines as one of the best practices behind their successful final designs. The other design team, T7, demonstrate a lack of HCD integration (level 0) defined in the rubric-B. However, none of them show an excellent level (level 4) of HCD integration into their design project reports. As an overall summary, the results are depicted in Figure 5.18 to provide the reader with an easy illustration. However, it is important to note that this is not a generalised view of the possible connections after the HCD scaffolding program; rather it provides a clear view of the results of the current effort.

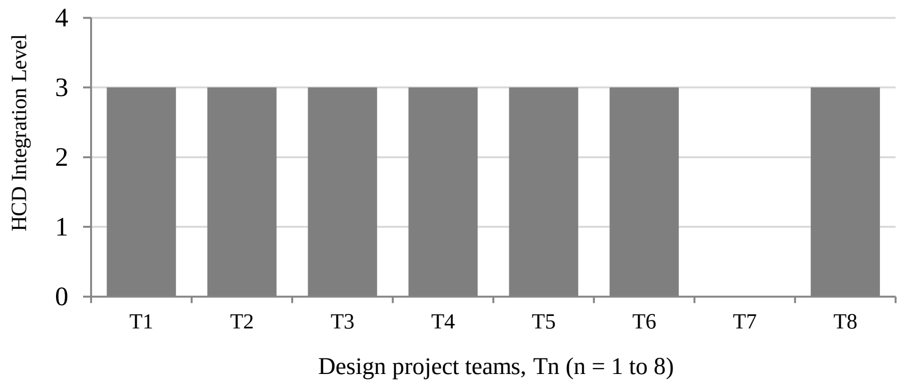


Figure 5.17: Level of integration of the HCD approach into design projects.
Level 0 – Lacks integration, Level 1 – Elementary integration, Level 2 – Developing integration, Level 3 – Adequate integration, Level 4 – Excellent integration

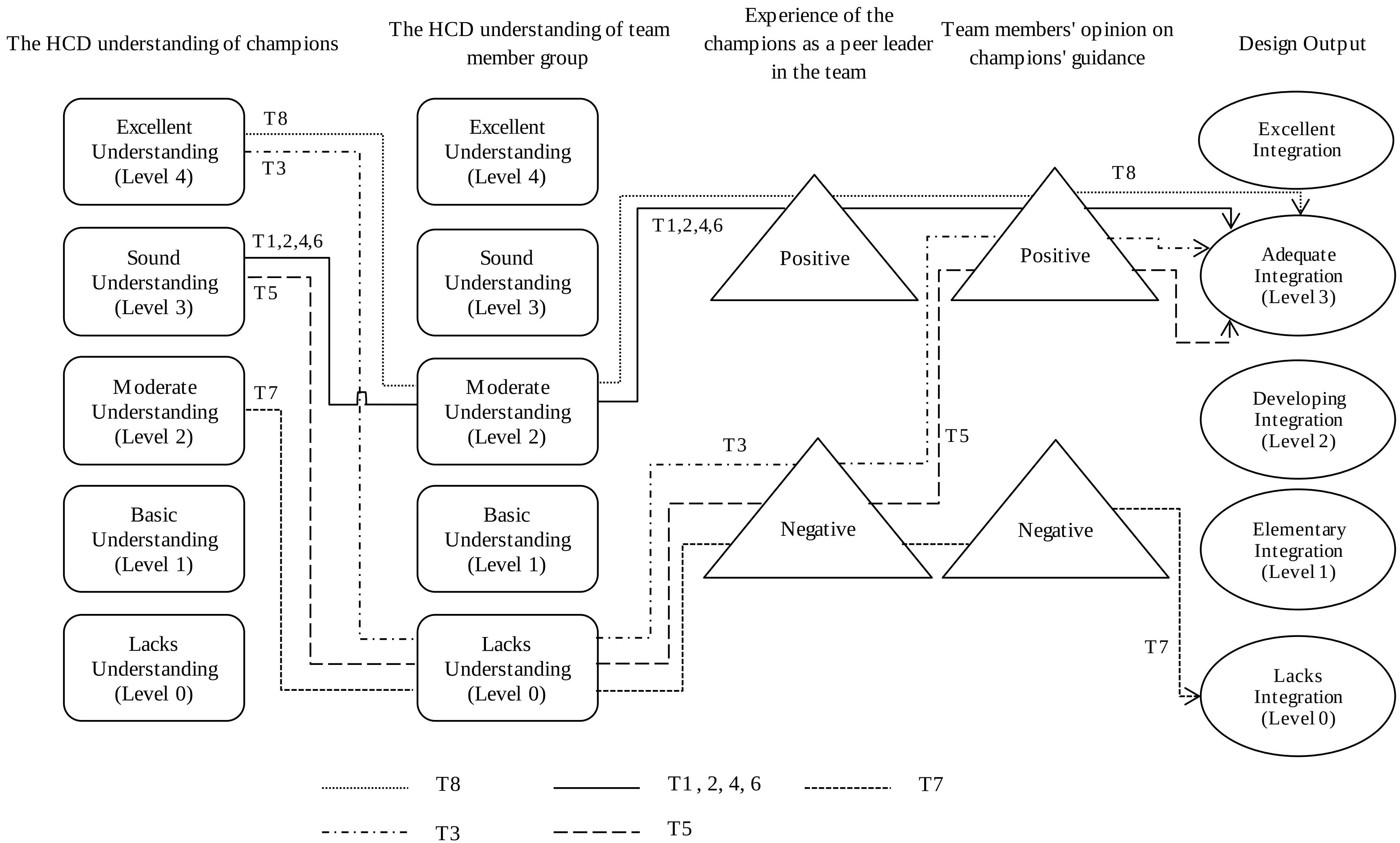


Figure 5.18: The summary of the results showing the inter-connectivity of the HCD understanding of champions and team members, peer leader experience of champions, team members' feedback on champions' facilitation, and HCD integration to the design project.

5.5.3.4 Feedback and suggestions of HCD champions and team members

All eight champions and 21 team members out of 33 appreciate the effort taken to deliver such a scaffolding program throughout the design project to motivate and facilitate them, especially being for the first time at AMC. According to them, the onboard HF activities and the introductory lecture are significant to encourage students to learn maritime HF and HCD. In addition, the 'designers meet end-users' workshop, guest lectures, and interactive discussion sessions conducted with HCD champions, receive the most remarkable feedback. Furthermore, they like the scaffolding materials such as weekly pamphlets, reference books, research articles, electronic database references, useful video links, and HF guidelines. Nine team members do not provide feedback or suggestions to improve the scaffolding program, even though they responded to the questionnaire. Three team members did not respond to the questionnaire. The students' key suggestions are:

- During the discussion sessions, discuss extra examples of real-world HF issues/design failures onboard ships and examples of success designs
- Arrange more 'designers meet end-users' workshop sessions
- Arrange guest lectures from seafarers who have experience in different areas but related to design projects
- Introduce more HF guidelines and teach the application
- Upload the scaffolding material and useful links to a shared folder where all students can access
- Plan other useful session instead of the lo-fi prototyping workshop
- Include HF and HCD theoretical sessions and practical sessions into the final year design project unit syllabus

5.5.3.5 The motivation of HCD champions and team members in practicing the HCD approach in their career

All eight champions state their inclination to apply the HCD approach within their future ship designs. Some of them want to gain further comprehensive knowledge on maritime HF and HCD prior to producing complex designs. In addition, HCD champions are willing to use the experience gained as peer leader to motivate and guide team members in their future design teams. Similar to the champions, 21 team members show their willingness to apply the HCD approach in future designs. Furthermore, they are enthusiastic to gain in-depth HCD knowledge in the future. As a summary, a total of 29 of students of the first cohort of participants of this study can be expected to use the HF and HCD knowledge within their future maritime designs.

5.6 Reflections and discussion

Keeping the aim of this research study in mind, I have decided to draw the reflections and discussion of action cycle 1 based on the following question:

> *Were the constructed teaching framework and the HCD knowledge dissemination activities delivered within this action cycle supportive to elevate the HCD understanding of participants? How should I improve further?*

Before commencement of this study, it was identified that none of the maritime design students of the selected cohort were exposed to HCD-related topics during their undergraduate studies (Abeysiriwardhane et al., 2014). In addition, the findings of the review of the previous design project reports also show the students' lack of HF and HCD understanding and awareness. Thus, the HCD understanding of champions at the commencement, which is actual/independent understanding level as described in the Vygotsky's ZPD theory (Vygotsky, 1978), can be graded as a lack of understanding.

Following a yearlong HCD knowledge dissemination activities delivered based on the teaching framework, the findings exhibited an improvement of the participants HCD understanding:

- A total of eight HCD champions elevate from 'lack' level to equal or above 'sound' level
- A total of 21 team members out of 33 elevate from 'lack' to 'moderate' level

In other words, the HCD knowledge dissemination from the facilitators to the HCD champions was effective in stimulating the HCD understanding of all eight champions to their ZPD potential as described in the Vygotsky's ZPD theory (Vygotsky, 1978) (see Figure 5.19). In addition, the HCD knowledge dissemination from the HCD champions to their team members (HCD champion concept) was effective in stimulating 21 of the team members' HCD knowledge to their ZPD potential (see Figure 5.20).

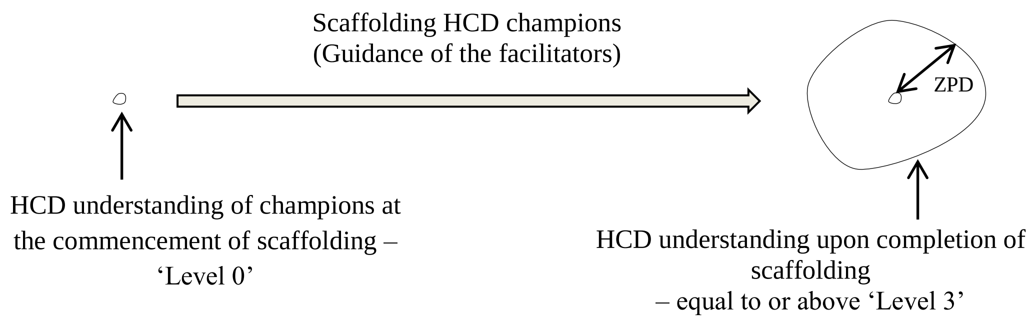


Figure 5.19: Scaffolding the HCD champions from 'lack' of HCD understanding to their ZPD potential.

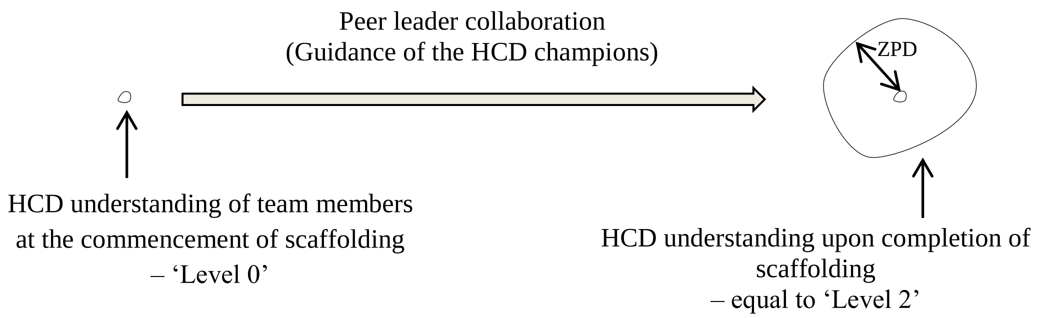


Figure 5.20: Scaffolding the team members through peer leader collaboration (HCD champion concept) from 'lack' of HCD understanding to their ZPD potential.

Eventually, as this research study expected through implementing the teaching framework, the facilitators assisted eight champions and those champions assisted 21 team members, in making an important transition and learning new knowledge. The HCD champions who guided these team members stayed within the group and promoted group interaction, providing suitable assistance to solve problems that team members could not solve on their own, the same way a more capable peer does within the PLTL pedagogical approach (Gosser & Roth, 1998). Hence, the findings show the effectiveness of the HCD champion concept to draw the team members to their ZPD, by having them work together on problems in the absence of facilitators, but with the help, guidance, or collaboration of a more capable peer. Therefore, the findings provide evidence to show that the constructed pedagogical framework and the knowledge dissemination activities utilised within this study are supportive in elevating the maritime students' HCD knowledge as well as creating unique maritime HCD champions who can guide and influence their colleagues.

Furthermore, the findings demonstrate the significant impact that the HF-related onboard activities had on students to encourage them in learning HF and HCD as well as to stimulate their knowledge. This was a good opportunity for them to practically test the design given to the seafarers to work (Kuo et al., 2000; Petersen, 2012; The Nautical Institute, 2015). The difficulties that seafarers face on board overwhelmed the students, showing them the consequence of the designers' awareness and understanding of HF and HCD to design user-friendly ships. This impact was demonstrated in all concept design proposals completed by students. All eight designs provided solutions to the issues seafarers face during the store and provision loading and transfer, and considered the daily access paths from the galley to the store rooms, which was exactly like one of the onboard activities. Students analysed daily logistical and personal access routes and tried minimising the walking distances from mess to stores, loading bay to stores, and loading bay to mess. They provided adequate provision loading and transfer facilities to overcome the difficulties they experienced during the onboard activities. In addition, students provided solutions to safely carry an injured person on a stretcher, and to transport heavy machinery equipment.

Furthermore, the following knowledge dissemination techniques are identified as effective pedagogical strategies during action cycle 1 to elevate the maritime students' HCD knowledge:

- Show many examples of real-world HF and HCD failure and success stories within ship design

  First I thought: why [do] we need HCD? We are not designing a ship; we are designing a marina. After I [was] introduced to real-world examples during the introductory lecture, I realised the HCD can be applied to any design. The users and tasks will be different from design to design.

  — champion of T5.

- Conduct interactive discussion sessions with students (Brookfield et al., 2012; Davis, 2009)

  Discussion sessions were helping us to engage more and more with the topic and communicate different points related to the topic.

  — champion of T1.

- Deliver guest lectures (Frederick, 1986; Gibbs et al., 1989)

  We [were] exposed to the real-world experience of end-user representatives through guest lectures. We never [thought] about those issues they explained to us.

  — a team member of T8.

- Introduce end-user representatives to the design students

  It was valuable and [an] honour for me and my team mates to have a discussion with a Submariner and that was the most valuable hour we [spent] during [the] design project time. Hearing from real users about their tasks and operational issues was incredible.

  — champion of T8.

However, still there are nine team members who suggested using designers' common sense to dictate the best compromise between comfort and efficiency. Besides this, they are not ready to acknowledge the significance of the designers' responsibility to 'design the problem out' (Rothblum, 2000) and suggesting getting users to adapt to the design. The HCD champion concept did not have an effect on these students and they remain at the level of 'lack' of understanding. Furthermore, the students' concept design proposals lack the provision of design solutions for secondary users. The CoU analysis in each design report is limited to primary users, key tasks, and major operational scenarios. Thus I understood that the CoU analysis knowledge of the students would need to be greatly improved.

To change this situation in action cycle 2, I identified the following advances based on the substantial contribution made by onboard activities, and other pedagogical approaches, to motivate students and to stimulate their HCD understanding:

- Add more onboard activities and spend more time with students during onboard stay
  Adding activities may allow students to practically experience more HF issues within the ship design and gain a better understanding of the practical aspects and the importance of HCD in seafarers' lives. In addition, through spending more time with students, I may possibly show them as many as practical difficulties the seafarers are facing due to the designers' 'uncommon' common sense to convince the students to change their 'common sense' perception of HF and HCD. Furthermore, I may guide them to imagining issues other than what they see on board the training vessel to consider HF in a much broader aspect within design.

- Improve the delivery of the HF introductory lecture
  I may discuss more deign examples to establish the significance of the designers' responsibilities to identify and eliminate the design issues during the early stages of the design process, rather than letting the 'train the operator' or 'shield against the problem' approaches to manage the problems (Rothblum, 2000).

- Improve the peer leader collaboration (HCD champion facilitation)
  During the next cycle, I decided to invite design project teams to discuss among themselves and to select a student they all agreed upon to become their HCD champion. By doing so, I expected to select a peer leader who has team support within the team that would help the champion to effectively disseminate HCD knowledge and to promote group interaction.

- Improve the effectiveness of the current scaffolding program
  Make improvements for the scaffolding program of action cycle 2 based on the findings and the students' suggestions as summarised in Section 5.5.3.4. In addition, I decided to allocate more time to teach and discuss the topic 'understand and specify the context of use'.

As an overall summary, it can be established that the constructed teaching framework and the HCD knowledge dissemination activities, which was constructed, implemented and tested within action cycle 1 with a total 41 maritime design undergraduates (consisting of eight HCD champion students and 33 team member students), is contributive towards improving HCD knowledge. Therefore, we decided to further test and validate the whole program including the above identified enhancements, with the next cohort of maritime design undergraduates.

Chapter 6

Action cycle 2

This chapter presents the detailed description of action cycle 2, which was conducted with the second cohort of participants of this study, students who enrolled in the design project unit at AMC in the academic year 2016. It comprises planning of a modified HCD scaffolding program based on the findings of action cycle 1, implementing the modified scaffolding program, data collection, data analysis, and results. The intended and unexpected findings of each action are reflected upon to further improve or to contribute to the body of the existing knowledge. In order to avoid repetitions within action cycles, the differences to its predecessor are only discussed within this chapter.

6.1 Planning of modifications to the action plan of cycle 1

During this stage, I re-read the findings, discussion and the reflections of the first cycle before planning modifications to the actions. Firstly, considering the substantial influence that the onboard activities had on the students' HCD understanding, I planned to conduct similar activities with minor modifications to make them more influential. I planned to increase the number of sessions of the evacuation activity by adding new path to the evacuation activity, allowing the students to learn more about the consequences of bad escape route designs on seafarers in the aftermath of an accident. Also, having permission from the faculty members, I intended to spend more time with the students having casual discussions about the difficulties that seafarers face due to poor design. I hoped it would allow me to influence the second cohort's viewpoint on HCD as common sense practice of the designers.

Secondly, during the HCD introductory lecture, I planned to discuss more on why the 'design the problem out' option should always be the first priority to minimise onboard HF issues rather than letting/forcing users to adapt to the design. This modification to the introductory lecture was also planned to influence the students' viewpoint on HCD as common sense practice of the designers. Thirdly, I planned to inform the design teams to have a meeting to select a student that they all agreed would become their HCD champion. Through this approach, I was hoping to secure team members' honest support and take part in the peer collaboration with their HCD champions, as I understood that the team participation and buy-in – support, not resistance – (Boivie et al., 2006; Carr, 1995; Petersen, 2012) was essential to attain improved results in HCD integration into the design projects. In addition, as a result, I was hoping to avoid the negative feedback from the team members on the guidance and facilitation of HCD champions which was seen in cycle 1.

Fourthly, during the familiarisation session with the second cohort of HCD champions, I planned to add a few modifications, as listed below:

- Share the findings of cycle 1 and explain the proposed modifications and the reasons for those
- Explain more about the accountability of the role as an HCD champion to guide and facilitate the team members
- Discuss the importance of team-work attributes in successful design projects (Koutsikouri et al., 2008)
- Request to be informed in advance of other commitments that could make them unavailable for the scaffolding sessions
- Ask them to give their authentic feedback if they faced any difficulties while working collaboratively with the team members to enable me to take alternative actions (Clark, 1972; Elliot, 1991; Feldman, 2007; McTaggart, 1993), such as the following:
  - Talk to team members individually to motivate and explain the significance of the HCD approach in designing usable ships
  - Show and discuss examples of the design issues and user-centred designs

Lastly, I did not want to make significant changes to the theoretical content of the HCD scaffolding program, since it showed a positive effect to elevate the participants' HCD knowledge. However, in order to improve it further and to make it student-centred, based on the students' feedback and my reflections, the following modifications were introduced:

- Add more examples of real-world HF and HCD failure and success stories within ship design

- Plan guest lectures from experienced seafarers from special fields, such as offshore and small craft fields
- Arrange individual ‘designers meet end-users’ sessions with each design team at different stages of the design project when they are ready for the consultation
- Allocate more time to teach and discuss the topic ‘understand and specify the CoU’
- Introduce the lo-fi prototyping concept and its importance to the HCD champions during the scaffolding sessions then let them decide whether they would like to prepare lo-fi prototypes on parts of their designs
- Create a shared folder to upload scaffolding materials where all students have access

As a facilitator and the researcher, I realised the difficulty I was going to face while arranging the separate ‘designers meet end-users’ sessions; however, as I also realised the value of it to stimulate the students HCD knowledge, I decided to prepare for it. Therefore, I contacted all experienced seafarers who helped me during the first action cycle and a few others from the offshore field and the yachting industry through my personal contacts, to make them aware about the second action cycle to request support when necessary.

Similar to the first action cycle, I arranged a group meeting with faculty members and HF specialist to discuss and get their support on the modified action plan. They agreed to provide their fullest support to conduct the second action cycle. Though the faculty members were happy to hear the students’ suggestion to include HCD into design project unit syllabus, they could not make any decision in this regard. However, they suggested that I present this research finding – after I complete the two consecutive years – to the AMC senior management, such as the principal of the school or the directors of the maritime engineering department, who have decision-making power to change unit syllabus.

6.2 Implementing the modified action plan and data collection

6.2.1 Onboard visit

As planned in Section 6.1, five HF-related onboard activities were conducted with the participant cohort during a five-day voyage on board the AMC research vessel, Bluefin (see Table 6.1 and Figure 5.1). A total of 25 students participated in these onboard activities. Before, during and after each activity, I spent time with the students having friendly discussions with them to change their ‘common sense’ viewpoint of HF by showing them the practical difficulties that seafarers are facing due to designers’ ‘uncommon’ common sense. I explained to them how common sense changes from designer to designer when making innovative designs and that one idea of common sense is likely to contradict someone else’s idea of common sense. Furthermore, I requested that they spend more time with the crew members to study their daily tasks – by frequency and demand – and issues they are facing while performing the tasks.

Table 6.1: HF-related activities carried out on board the AMC research vessel Bluefin in cycle 2.

Activity	Description
1) Evacuate an injured person	Students were requested to carry an injured person on a stretcher from the machinery space to the main deck.
2) Check accessibility/operability of valves	Students were requested to observe the accessibility and operability of valves available in the engine room and the main deck of the vessel.
3) Check space utilisation	Students were requested to observe the space utilisation in accommodation, washroom space and recreation space and check if the design appropriately addressed the comfort of seafarers' lives.
4) Carry provisions through the ship	Students were requested to carry a medium-size provision box from main deck to stores then to galley and to garbage station.
5) Evacuate an injured person from laundry space to main deck of vessel	Students were requested to carry an injured person on a stretcher from the laundry space to the main deck.

The students' feedback and my observations during the activities showed me the impact of the modified actions on the students' HCD perspective, awareness, and understanding of the maritime HF issues. As I have noticed, students got an opportunity to learn more during evacuating an injured person from the laundry space than from the machinery space. Figure 6.1 illustrates some of the pictures taken during the evacuation activities. Furthermore, this was supported by the students' explanations of their experiences during both scenarios as in the below quote.

> It was [more] difficult to evacuate from [the] laundry space than [from the] machinery space. Even space was also limited to assemble the stretcher inside the laundry. Personal access routes were extremely poor. It took [a] long time to think what to do and how we carry the stretcher upstairs. If the person was really a patient, then he would have died.
>
> — a student after the evacuation activity.

All of them mentioned the significance of considering HCD approach within the early stages of the ship design process (see below quote). They were able to identify design failures during the activity such as steep stairs, insufficient landing spaces, obstructions in the evacuation routes, insufficient headroom clearances in stairwells, and cramped entry and exit points.

> I [am] completely convinced as a future designer, we must consider these emergency scenarios when we design ships. Otherwise that design will dissatisfy the users of it. They will definitely blame us.
>
> —a student after the evacuation activity.

Figure 6.1(a) Figure 6.1(b) Figure 6.1(c)

Figure 6.1(d) Figure 6.1(e) Figure 6.1(f)

Figure 6.1: An activity of students carrying an injured person on a stretcher from the laundry space to the main deck of AMC research vessel Bluefin. (a) Assembling the stretcher; (b) Strapping in patient; (c) Obstructions while carrying the stretcher from laundry space through accommodation area; (d) Mission stopped while discussing different ways of carrying the patient; (e) Stretcher with patient almost vertical due to poor design of the stairs; (f) Door obstructions/very limited landing space while carrying the patient to the main deck. (Pictures used with consent)

I noticed the students' engagement during the activities was improved in the second action cycle. They were interviewing the ship crew members during the activities, including the Chief Engineer, Assistant Engineer and Chief Cook. In addition, they were taking down notes while participating in the activities. As I noticed, they were trying to improve their knowledge by asking questions regarding the different tasks, the frequency of the tasks, and the operational procedures. This was purely the impact of the guidance and extended engagement I had with the students in this action cycle. At the end of the second activity, students had discovered that there are frequently operated valves which have very poor accessibility, as seen in Figure 6.2.

Figure 6.2(a) Figure 6.2(b)

Figure 6.2: An activity of students checking accessibility/operability of valves inside engine room of AMC research vessel Bluefin. (a) Regularly used valve position leads to awkward work posture; (b) Operators' position to reach a valve. (Pictures used with consent)

While checking the space utilisation in accommodation and recreational spaces, they were able to identify design failures such as insufficient headroom, poor accommodation layout, insufficient ventilation, insufficient natural lighting, and excessive vibration in the room next to the engine room. After the provisions transporting activity most of the students realised the importance of doing analysis of the logistical and personal access routes during concept design to identify the most user-friendly and efficient path to accomplish the task. Since the provisions had to be loaded via the aft of the vessel and the provisions stores were located in the forward part of the accommodation, students experienced difficulties while carrying provisions boxes. The personal access route to accomplish the task had many obstructions (see Figure 6.3).

> It was good that the boxes were empty. Otherwise it could have just a dream for me to carry heavy provision box from [the aft] of the vessel to all the way forward of the vessel passing such obstructions. Cannot imagine how this is possible for the staff.
> —a student after the provision exercise.

Most interestingly, none of the students suggested using common sense to dictate the best compromise between comfort and efficiency. This feedback showed me the usefulness of the effort I had taken to change the students' 'common sense' perception by spending extended time with them during the onboard activities compared to cycle 1.

Reflections: The onboard stay and modified HF activities had a great influence on the students' HCD perspective, awareness, and understanding of maritime HF issues. The guidance and extended engagement I maintained with individual students situated me in the position of 'change agent' (Rapoport, 1970; Zuber-Skerritt, 1994). To achieve this, the faculty members were exceptionally supportive to my request to allocate more time to do HF activities compared to the first cycle. This may be due to their realisation that the importance of the HF activities is not less so than the technical activities students carried out during the onboard stay.

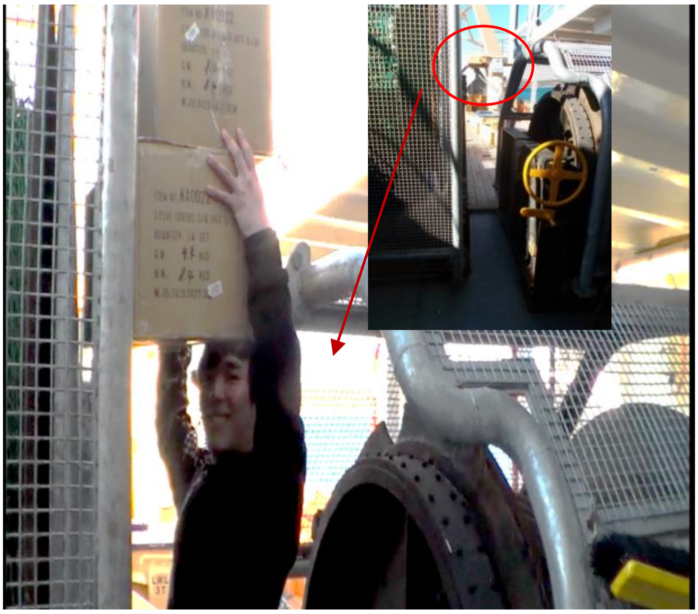


Figure 6.3: An activity of students checking logistical and personal access routes; Carry provision from main deck to stores of AMC research vessel Bluefin. (Picture used with consent)

6.2.2 HF and HCD introductory lecture

The modified introductory lecture was delivered as planned in the Section 6.1 (see Appendix F). For organising and delivering this activity I took support from the faculty members and HF specialist. The students were more engaged in the discussion when the HF specialist showed few pictures of onboard accidents and asked them to give their opinions on how to eliminate those problems. Majority of them individually as well as in-groups had taken effort to find out causes for those accidents. They identified that the causes can be traced back to the design of those vessels. Then they suggested eliminating or minimising such during the design stage of a ship by taking user working scenarios into account. Most importantly, no one gave answers like 'let them wear safety shoes' as during the first action cycle. This may be due to the extended time spent explaining why the 'design the problem out' option should be the first priority in minimising the HF issues on board. In addition, this also may be a result of the extra time I spent with students during the onboard stay to explain difficulties that seafarers face when they have to adapt to less user-friendly designs.

6.2.3 Invitation for HCD champions

The invitation flyer which was used during the first action cycle was sent to all students who enrolled in the design project unit (see Appendix G). In addition, with the support from faculty members, I informed all design teams to discuss among themselves carefully and select a student that they all agreed upon to become their HCD champion. Therefore, the students were given more time than in the first cycle to respond to the invitation. In this cycle, out of 12 design project teams, representative students from eight design project teams responded (see Table 6.2). The scopes of the remaining four design projects were numerical analysis of existing devices such as wave and wake attenuating devices and wave energy converter devices, and experimental analysis of an autonomous underwater vehicle. As a result, out of 40, 28 maritime design students (eight champions and team members) were interested in participate the study as the second cohort. Enrolment has increased, by about 7% compared to the first action cycle.

Table 6.2: List of design projects included in action cycle 2.

HCD champion	Design project name
T1	Submarine support ship design
T2	Submarine rescue vehicle
T3	Small ferry design 1
T4	Passenger ferry design
T5	Small ferry design 2
T6	Mobile heavy lift landing craft design
T7	Heavy lift crane barge
T8	Wave energy generator service vessel

6.2.4 Familiarisation session with HCD champions

The familiarisation session with the HCD champions was conducted as planned during the planning stage of this cycle (see Section 6.1). I received the consent from all HCD champions to participate in this study. Most interestingly, I noticed that all of them were students who had participated in onboard activities. This demonstrated the careful selection of the HCD champion by team members in order to guide them throughout the design project.

6.2.5 HCD knowledge dissemination activities – 'modified HCD scaffolding program'

I referred to the 2016 academic calendar and identified 11 possible weeks without interfering with examinations, study leave and semester breaks. The sessions were conducted Fridays from 09:00 am to 10:30 am, similar to in cycle 1, with the support from faculty members, the HF specialist, and experienced seafarers. For a detailed explanation of modifications to each scaffolding session please refer to Appendix H.

At the end of every session I encouraged HCD champions in peer collaboration and requested that they disseminate the HCD knowledge to their team members and guide them within the design process. This assisted them to understand their role in small group collaboration as a more capable peer. In addition, I followed up with them in every session to receive their authentic feedback. If anyone was facing difficulties while working collaboratively with their team members, this enabled me to take alternative actions.

The relevant scaffolding materials were distributed at the end of each session. In addition, based on the students' feedback, all scaffolding materials were uploaded into a shared folder where any student could access them. Based on the availability of the experienced seafarers, some of the guest lectures and 'designers meet end-users' sessions were arranged on days other than Fridays.

<u>Session 1</u>

Topic: Introduction to HF, Ergonomics, and HCD.

Actions: In addition to the topics covered in scaffolding session 1 of cycle 1, a HF failure story and a success story were introduced and discussed with HCD champions.

Outcomes: All champions attended the scaffolding session. During the class exercise, which was the 'Santa Claus Exercise', this team of champions were more engaged than the first cohort of champions. The exercise did not appear funny for any of them. They figured out more interesting points, such as designing adjustable clothes; designing an adjustable seat on the sleigh for Santa considering the changing body size, strength and physical capacity; making provisions for the range of variability to be expected in the Santa population. One champion added the point of designing suitable clothes, seat and sleigh for a female Santa using 'Women Santa' anthropometry data. These points were exactly related to the theory lessons discussed during the session under introduction to ergonomics. The engagement of the champions in the discussion was much improved when I introduced a HF failure story and a success story. I noticed all champions recommended to 'design the problem out' as their option to avoid HF failure.

Reflections: Similar to the reflections made during the action cycle 1, I understood the impact of presenting real-world success and failure stories of HF and HCD and discussing them with undergraduates to make them engage with the topic (Cooperstein & Kocevar-Weidinger, 2004; Duffy et al., 1993; Haack, 1972), especially non-technical topics such as HF and HCD. In addition, these outcomes further provided evidence to show the effectiveness of utilising of 'discussion' pedagogic approach within traditional lecture context in order to promote active learning (Brookfield & Preskill, 2012).

Session 2
Topic: First step of HCD activities – Plan the HCD process

Actions: In addition to a short lecture similar to cycle 1, a HF failure story and a success story were introduced and discussed with HCD champions.

Outcomes: All champions attended this session. All of them were pleasantly engaged with the HF specialist and myself during the discussion of the failure story and raised few points, listed below.

- Failure story: Offshore seafarer climbing on top of stored pipes in order to guide a load.
- Champions:
    - Clearance/proper space between components/equipment is important
    - Visual access/good visibility to necessary components is important to facilitate accurate and efficient task completion
    - Laydown area and location of the pipe rack did not take into account the lifting work that would also need to be conducted in the same area

Reflections: Real-world HF examples were more tangible for students and therefore identified key functions performing within the particular area in order to plan for usable design. I understood that particularly this practical approach I have chosen to deliver the HCD knowledge was influential as Petersen (2012, p. 187) also suggested that 'engineers are inherently practical people. Do not lecture. Shut up, and engineer'.

Session 3
Topic: Second step of HCD activities – Understand and specify the context of use (CoU).

Actions: A short lecture similar to the first cycle was conducted with a slight modification to it. Before the design project briefing session, I showed two pictures of a particular task on board a ship, which was the 'mooring task', and invited champions to a discussion on people, tasks, risks/hazards, and the operational environment. This was done to stimulate and encourage student learning CoU and to add variety to the session.

Outcomes: All champions attended the session. During the discussion on the 'mooring task', champions were well engaged and identified key roles in the mooring team, such as the mooring team supervisor, senior officers and assistants. With the help of facilitators, champions identified tasks such as communicating with the bridge team, tug crew and shore people; checking all the mooring equipment including the mooring winch, drums and windlass; checking the mooring lines; checking the load sensors of mooring winches; and communicating within the team. In addition, they mentioned the risks involved in this operation, such as poor overview; crossing lines; slip, trip and fall hazards; sea rising; poor communication; and adverse weather.

Unlike cycle 1, all the champions clearly briefed us on their projects. All of them stated at least a few primary users and secondary users (see the below quote).

> Identified mother ships' crew as permanent primary users. Submarine crew also as primary users but they are not permanent users since they use the mother ship during the time of replenishment only. Maintenance engineers, shore based people who are responsible for support ship as well as submarines, cargo loading and handling people as secondary users of the design.
> —champion of T1.

At the end of the session four champions talked to me and showed more examples of failure and success stories within maritime design similar to the examples I explained to them in session 2. Not only that they were clearly explained the design solutions for eliminating those failures. In addition, they requested articles related to safe mooring. Just after the session, I emailed them a few articles and useful links related to the safe mooring of a ship.

Reflections: I further understood that presenting and discussing real-world examples of HF and HCD with maritime design students was highly influential to improve their critical thinking skills (Duffy et al., 1993) and it motivated them to find more examples.

Session 4

Part A

Topic: Continuation of the second step of HCD activities – Understand and specify the CoU.

Actions: In addition to the teaching in cycle 1, I used the 'wind farm support vessel' design by Damen Shipyard to explain how those designers analysed CoU within their use-centred design process. Furthermore, a mind-map (Szulevicz & Tanggaard, 2017) was prepared including videos, pictures, and articles related to their design projects, which could help to stimulate knowledge about users, their tasks, and their physical, social and organisational environments. This map was shared with all champions and requested them share it with their team members. Furthermore, I introduced the lo-fi prototyping concept as an option to stimulate CoU knowledge and to evaluate design alternatives at any stage of the development process. I asked that the champions decide whether they would like to prepare lo-fi prototypes on part of their designs. In addition, I informed them of the plan to arrange 'designers meet end-users' sessions for each team and I invited champions to discuss with the team members and inform me of their need to meet user representatives according to the progress of the design.

Outcomes: All the champions attended this session and they were pleasantly engaged in the discussions with the HF specialist and me during the session. At the end of the session, champions from T1, T3 and T4 showed me a few useful videos they had found and explained how useful those were to find out CoU of their design. As they spoke, the whole team got together and searched the internet to collect those videos.

Reflections: The discussion with the champions provided evidence to show the effectiveness of the motivation I gave them to improve peer collaboration at every session. Furthermore, I did not have to take alternative actions to improve group collaboration since none of the champions mentioned issues in group collaboration and/or knowledge dissemination.

Part B

Based on student feedback from the first cycle, I did not conduct the lo-fi prototyping session.

Session 5

Part A

Topic: Continuation of the second step of HCD activities – Understand and specify the CoU.

Actions: As I planned to allocate more time to teach and discuss the topic 'understand and specify the CoU', this session was also utilised to that. After a short lecture, a HF failure story and success story, with respect to the CoU consideration, was discussed with the HCD champions.

Outcomes: Champions were extremely happy about the introduction given of the virtual tours of ships to learn different working spaces, personal access routes, and complete details of different ships. The champions had never been informed about these sources. According to their feedback at the end of the session, they were ready to learn more about real working environment and layouts of ships using such sources in the future. In addition, they expressed their feedback on the mind-map (see the following quote):

> The bridge tour video was really useful to find out [about] people who [worked] on the bridge and their duties.
> —champions of T1, T3, T6, and T8.
>
> I realised [that there are] bad condition[s] when the sea is rough in New Zealand waters exactly where our design is going to be operated. I should be aware.
> —champion of T4.

After the discussion of the failure and success stories, a few HCD champions inquired about regulations for layout designs that can fulfil user comfortability and workability. The HF specialist then pointed out that HF guidelines do indeed help, but they do not in themselves solve the problem. She further pointed out that it is a good practice to use them but designers' knowledge on HCD is paramount. One champion was sick on this day and therefore the total attendance was reduced to seven.

Reflections: Based on the positive feedback of the champions on the mind-map, I understood the consequence of such approaches to promote active knowledge construction and critical thinking through collaborative brainstorming (Sailin & Mahmor, 2016; Willis & Miertschin, 2006). In addition, I understood that designers are naturally enthusiastic about sticking to the rules or any guiding documents as described by Rasmussen (2005). Nevertheless, they should be mindful to use those documents only as a best practice, as they do not themselves solve the problem.

Part B

Topic: Guest lecture presented by experienced seafarer.

Actions: One hour was allocated to a guest lecturer from the field of offshore on the same day from 13:00 pm to 14:00 pm. All champions and team members were invited. As I requested the guest lecturer to include not only his current experience but also his previous career experiences, this lecture covered nearly all hierarchical levels of ship deck officers.

Outcomes: Most of the students were engaged with the speaker during the lecture. As an example, students were asking questions (see below) during an explanation of the scenario of an offload tanker coming alongside an offshore storage ship to undertake a ship-to-ship transfer of cargo.

- How many of the deck crew will be involved in this operation?
- What are their major tasks?
- Explain risks and hazards associated with this operation?

HCD champions and their team members talked to the lecturer after the session and they were requesting further explanations of critical tasks within other offshore operations, also requesting the relevant videos and materials from him. The guest lecturer answered all the questions and further explained the design issues they have within this area of operation, such as visibility, communication, maintenance and unnecessary obstructions on the deck.

Reflections: Similar to the reflections I made for the guest lecture session of action cycle 1, it was clear to me that this pedagogical tool can enrich the overall learning experience of the students.

Session 6

Part A

Topic: Third step of HCD activities – Specify the user requirements.

Actions: In addition to the topics covered in cycle 1, a HF failure story and a success story were introduced and discussed with HCD champions.

Outcomes: All champions attended the session. After the session, I talked to the champion who had missed session 5 and briefed him on the topics discussed during the class and the guest lecture. Furthermore, five champions indicated that their teams were ready to consult with end-user representatives. Two teams preferred to meet an end-user with experience on submarines. Another team, who designed a passenger ferry, favoured talking to a seafarer with passenger or Ro-Ro ferry experience. The remaining two teams did not request a seafarer with experience in any particular vessel type, but wanted to talk to any seafarer. I managed to arrange these separate consultation sessions for them and it is discussed at the end of these scaffolding sessions (see ‘designers meet end-users’ sessions).

Most interestingly, a few champions showed me few online virtual tours of ships that they had found. I was happy to see such enthusiasm from these teams and this was evidence of the effectiveness of the modified actions taken within this cycle.

Reflections: I realised the usefulness of my decision to plan these 'designers meet end-users' sessions when the design teams prefer to meet them. According to many educational researchers, this student-centred approach is considered as 'inside out' approach and they believe that the 'inside' are students who know what is best for them (O'Neill & McMahon, 2005; Stefani et al., 2000).

Part B

Topic: Guest lectures presented by experienced seafarers.

Actions: Two guest lectures from experienced seafarers (a Chief Engineer and a Deck Cadet) were delivered on the same day from 13:00 pm to 15:00 pm. All champions and team members were invited and faculty members helped me to organise this session.

Outcomes: Students showed their interest in learning from experienced seafarers through engaging with them after their talks. Not only champions but also the team members directed questions (below) to them.

- How many of the engine crew will be working inside the engine room in usual operation? And emergency maintenance situations?
- How do engine room crew communicate with bridge crew when departing and arriving at the port?
- Which orientation do you prefer for beds and bunks?
- Which direction do you prefer for ladders and stairways?
- How many of the crew will be working on the bridge during departure and arrival at the port?

Reflections: Similar to the reflections I made for the previous guest lecture session, the outcomes further proved the influence of this pedagogical tool to enhance the overall learning experience of the students through real-world experience of the guest speaker.

Session 7

Topic: Fourth step of HCD activities – Produce design solutions to meet user requirements.

Actions: I followed a similar session plan as conducted during the first cycle.

Outcomes: All champions attended this session. The remainder of the champions who had not requested user consultation sessions yet, showed their eagerness to meet end-user representatives.

Reflections: As I reflected after the session 6, part A, I further understood the effectiveness of using 'inside out' approach (O'Neill et al., 2005; Stefani et al., 2000).

Session 8

Topic: HF guidelines.

Actions: Instead of the topics covered during this session in cycle 1, a short lecture was delivered that covered HF guidelines and using them to produce design solutions. This session was planned based on the request of the HCD champions.

Outcomes: All the champions attended this session. The HCD champions were actively engaged during the discussion of the HF and Ergonomic guidelines including crew habitability, bridge visibility, engine room layout ergonomic requirements, and shipboard fatigue. They were enthusiasts of HF guidelines.

Reflections: As I have noticed the engagement of the champions during the discussion sessions so far was improving.

Session 9

Topic: Fifth step of HCD activities – Evaluate the designs against requirements.

Actions: This session was similar to the scaffolding session number 8 of cycle 1.

Outcomes: The attendance was reduced to six. Attending champions showed their enthusiasm by asking questions and taking down notes while the HF specialist explained methods to evaluate the designs against user requirements.

Reflections: The champions who did not attend this session had to attend their research project meetings on very short notice. Though they informed me a few hours before the session, it was impossible to change the session date or time.

Session 10

Topic: Introduce HF evaluation software (HumanCAD®).

Actions: I followed the same session plan as conducted during the first action cycle.

Outcomes: All champions attended this closing session of the scaffolding program. Two champions wanted to evaluate their designs using ergonomic 3D evaluation software as they were ready with the 3D models of some parts of their designs. Other champions were not ready because they did not have enough time to prepare 3D models although I motivated them to make such drawings in the beginning. After the session, I talked to the champions who missed the previous session, and briefed them on the topics discussed to make sure they did not miss any lessons.

During the friendly discussion I had with the champions at the end of this session, all of them requested that HCD be included into their design project unit syllabus, making it compulsory for all design undergraduates to learn and apply maritime HF and HCD during the design projects.

Designers meet end-users sessions

I invited experienced seafarers to have consultation sessions with the design teams as end-user representatives. Five of them were the same seafarers who helped me during cycle 1: one Submariner and four Master mariners. The other two were a Chief Engineer of commercial vessels and super yachts, and a Deck Officer of a passenger ferry. All of them accepted my invitation without any objections. They agreed to provide their feedback and suggestions to improve the designs and stimulate the future designers' HCD knowledge. Upon the confirmation from them, I organised the meetings accordingly with HCD champions as explained below.

Submarine support ship design team (T1)

First session

The champion of the submarine support ship design and his team members spent nearly one hour with their end-user representative during the first session. The HCD champion and his team members were well prepared to meet the end-user representative, with their preliminary design sketches and a list of questions. One of their team members did not attend the session due to another lecture he had to attend at the same time.

First, the students briefed the end-user representative of the design project objectives and explained their understanding about primary users and secondary users of their design. The end-user representative, as a Submariner, would be one of the real primary users of a design such as this. Upon request from the students, the Submariner explained his experience including his duties as an officer of a submarine; the hierarchy of a submarine crew; how this hierarchy system works when the submarine crew accesses the submarine support ship during replenishment; how the submarine replenishing happens; how they load the torpedoes; and issues usually faced by submarine crew during operation. The students asked questions on loading procedures of bunkering and provisions; workshop capabilities required during replenishment of a submarine; access to submarines; turnaround times of submarine crews; and training facilities of the submarine crew required. The end-user representative answered all questions based on his experience.

Second session

During the second session, the team was prepared with the preliminary general arrangement drawing of their design, and facilitated a walkthrough of the designs for the Submariner. He appreciated the effort this team had taken to use the CoU-based information he provided in the previous meeting into the design of the general arrangement. The team exhibited user-friendly design solutions such as a hospital with easy access to the helideck, training room, private room/prayer room and workshop; more room for storage; crane assist with stores/refuse handling and assisting fender deployment; sufficient spaced galley and mess room; day stores within the galley with sufficient space. However, the Submariner provided his feedback on the location of the workshop; crane reachability when the two submarines berthed on port and starboard sides; submarine fuelling gantry arrangement; and senior sailors/junior sailors' accommodation arrangements. He further explained the hierarchy of a submarine crew and their need to maintain the same segregation when replenishing. However, he confirmed the need of comfortable stay for every sailor since they are living in cramped spaces during the operation.

Third session

This team was well prepared for their third consultation session with an experienced Chief Engineer. They facilitated a walkthrough of their preliminary layout drawing of the engine room to the engineer. The team member who was responsible for engine room layout design explained how he was trying to keep sufficient space around machinery ensuring that maintenance, repair and housekeeping tasks can be performed effectively while minimising the risk of injury. He further explained his idea of allocating space for a noise-protected communication station in addition to the control room but within the general area that most maintenance and watchkeeping activities take place. The end-user representative appreciated the effort this team had taken to understand the users and tasks within the engine room. He provided feedback and suggestions on reducing the number of small and large generators (four smaller and two large) and to consider using two or three large ones to save space. He further suggested sanitary facilities at the same level of the engine room (if possible), easy access to the engine room stores, and sufficient walkway width for heavy machinery movements. Furthermore, he explained maintenance schedules, and the ease and difficulties of different engine types available in the market based on his experience.

Fourth session

This team consulted experienced Captain of a ship to facilitate a walkthrough of their preliminary layout design of the bridge. The champion and his team member explained how their design took into account the console configuration dimensions for standing and sitting positions considering the Australian Navy anthropometric data, requirement for field of vision, field of vision around the ship, front window inclination, and clear route across the wheelhouse. They were referring to the videos linked to the mind-map, virtual tours, and HF guidance documents I had provided them during the scaffolding sessions. The end-user representative valued their effort and provided suggestions and feedback to improve the design. He suggested to provide sufficient hand or grab rails to enable personnel to move or stand safely; sanitary facilities with easy access; a less painful left-to-right viewing angle of consoles; sufficient leg room for the console; a chart table to accommodate all chart sizes; sufficient visibility of the ship side from the bridge wing; and a user-friendly bridge–wing communication system between the workstations for docking.

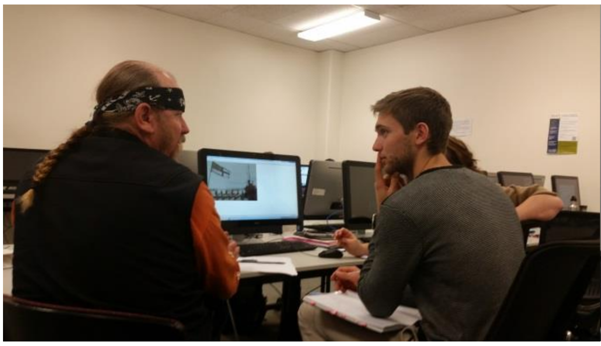


Figure 6.4 (a)

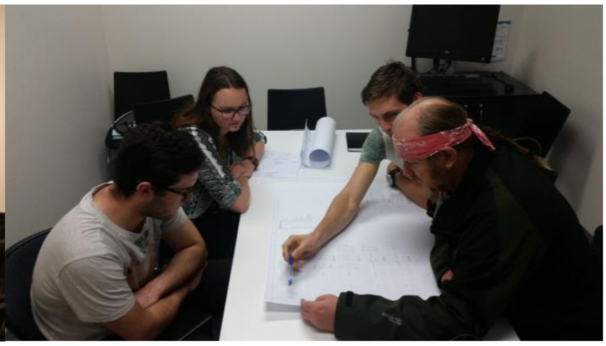


Figure 6.4 (b)

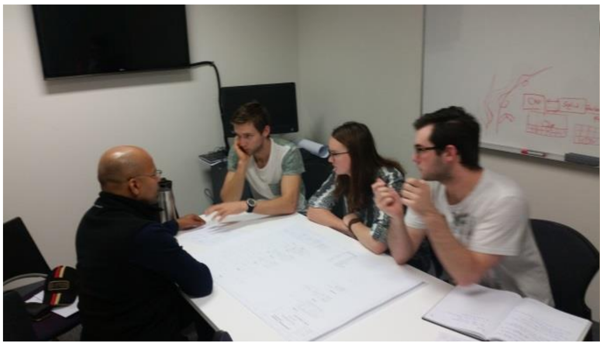


Figure 6.4 (c)

Figure 6.4 (d)

Figure 6.4: HCD champion and team members of T1 having discussions with end-user representatives. (a) First session with Submariner; (b) Second session with Submariner; (c) Third session with Chief Engineer; (d) Fourth session with Captain. (Pictures used with consent)

Submarine rescue vessel design team (T2)

The champion of the submarine rescue vehicle design team and his team members had a friendly discussion with their end-user representative: Submariner. They asked him to describe his experience and duties as a Submarine Officer. Though one of the team members preferred to hear the Submariners' experience of a submarine rescue vessel, he did not have such experience in a disabled submarine. However, he mentioned valuable points to consider while designing, such as the stressed situation of the submariners under such disabled conditions, different sizes of submariners, access ladder design, space utilisation inside the rescue vessel, and a transfer skirt design in order to maintain the pressure to avoid further risk to the escapees from the disabled submarine.

Figure 6.5: HCD champion and team members of T2 having a discussion with end-user representative – Submariner. (Picture used with consent)

Small ferry design team 1 (T3) and Small ferry design team 2 (T5)

Since both design teams were designing a small ferry, they were happy to consult an end-user representative who had yacht and small ferry experience. I managed to find a Master mariner who had many years of experience on board yachts and small ferries. These students were also well prepared for the session and firstly briefed the user representative of the design project objectives. They requested that their user representative share his duty and experience with them. They asked questions of the user representative on approximate crew requirements for similar designs; their major tasks and procedures; risks they face during those tasks; loading and unloading of the passengers; teamwork on the bridge; the communication with shore people; disability access requirements; and sanitary facilities in the case that the crossing time is less than two hours. The end-user representative explained expected crew requirements for such designs, expected tasks, simultaneous tasks users would have to perform, and criticality of the tasks while providing services. He especially explained the experience he had with disability access and the loading and unloading of passengers.

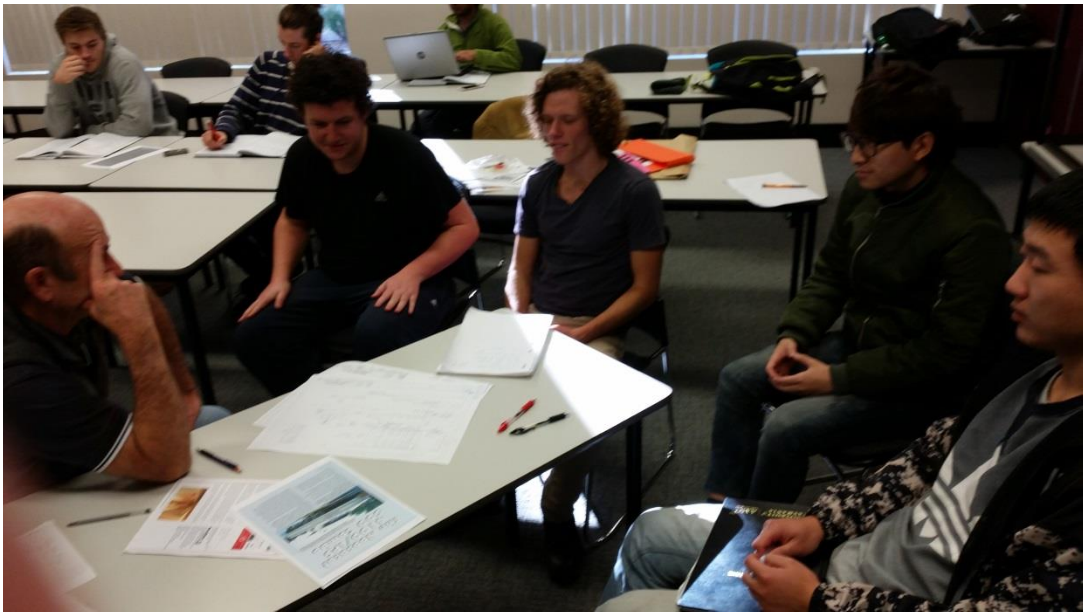


Figure 6.6: HCD champion and team members of T3 having a discussion with the end-user representative – Master mariner. (Picture used with consent)

Figure 6.7: HCD champion and team members of T5 having a discussion with the end-user representative – Master mariner. (Picture used with consent)

Passenger ferry design team (T4)

The HCD champion and the team members facilitated a walkthrough of their preliminary general arrangement and gave a briefing of the project objectives to the end-user representative. They were not clear about the crew requirements of the vessel and the end-user representative provided a clear explanation based on his experience with different passenger ferries. Furthermore, he explained the major tasks of individual crew members and how they work as a team, especially on the bridge and in the engine room. In addition, the discussion went further by answering the team members questions on securing vehicles to the deck, especially to support them during the harsh weather conditions;

vehicle lanes for proper parking and accessibility; issues on accessibility from the vehicle deck to the passenger decks; and disabled access.

Figure 6.8: HCD champion and team members of T4 having a discussion with the end-user representative – Master mariner. (Picture used with consent)

Mobile heavy lift landing craft design team (T6)

Similar to the other teams, this team champion and his members were well prepared to have discussions with the end-user representative. They facilitated a walkthrough of their preliminary layout drawings, general arrangement and engine room layout, and briefed the end-user representative on the project objectives. Furthermore, they showed their list of primary users, secondary users, and the requirements based on their CoU analysis. The end-user representative appreciated the effort that the team had taken to understand the CoU of their design and added feedback and suggestions as below:

- Since one of the major tasks of this vessel is personnel relocation, consider adequate shelter and first aid for disaster stricken personnel
- If there are disabled people, consider how you are going to provide boarding and disembarkation facilities and easy personal access within the ship
- One medical doctor and deck hand will not be sufficient to fulfil the objectives of the vessel
- Consider lift-on/lift-off operation for this vessel.

Specifically, they mentioned the difficulties they were facing while producing design solutions to cramped spaces since it is just a 15 metre vessel. The user representative explained his experience working in cramped engine rooms in yachts and how the designers can provide a decent working environment by considering key points, such as provide easy accessibility to frequently-operated valves and service components; selecting the proper engine size, which can save space within the engine room; provide good ventilation and lighting; avoid steps within small areas of the engine room; and provide good communication system between the wheelhouse, deck and engine room.

Though this team needed my support to meet an end-user representative who had sailing experience in a Lighter, Amphibious Resupply, Cargo (LARC) vessel, which is similar to their design, I could not find an end-user representative with such experience. However, the experienced seafarer I linked with this team who had yacht-sailing experience as a Chief Engineer provided feedback to the team to improve the design. He personally did research to find out more about LARC and advised students to visit one such vessel located in Queensland, Australia. A few weeks after this meeting, the champion and one team member visited the vessel and gathered information they needed regarding the operation of the vessel. However, since that vessel was converted to a tourism operation, the students informed me that it was a very limited opportunity they had to see the vessel.

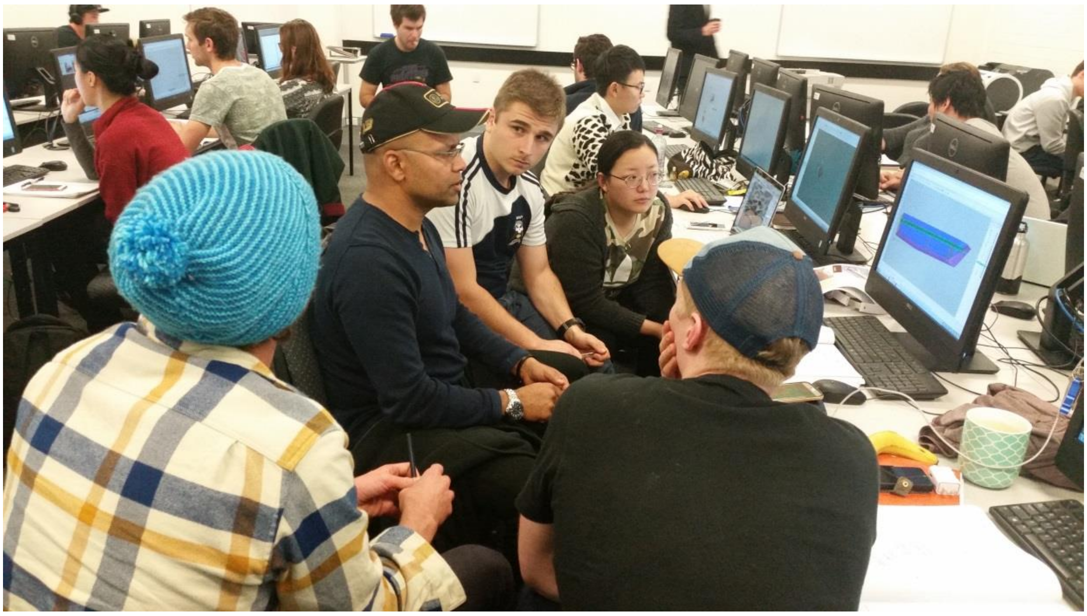


Figure 6.9: HCD champion and team members of T6 having a discussion with the end-user representative – Chief Engineer. (Picture used with consent)

<u>Heavy lift crane barge design team (T7) and Wave energy service vessel design team (T8)</u>

Since both design teams were designing vessels to facilitate the wave energy generating field, they were happy to consult an end-user representative who had offshore supply vessel experience. I managed to find an experienced Master mariner who had many years of experience on board such offshore supply vessels. Similar to the other teams, these two teams were also well prepared with the concept design thoughts and facilitated a walkthrough of their preliminary drawings for the end-user representative.

While briefing the end-user representative of their projects they exhibited the idea they had on their primary users (ship crew, maintenance engineers/special personnel, and divers), secondary users (assisting tugs, and shore-based communication centres), and their major tasks, such as lifting operations in shallow water environments, remotely-operated vehicle (ROV) operations, and maintenance work in water with the use of ROV or divers. The end-user representative added his experience to their understanding and explained expected crew requirements for such designs, the expected tasks, the simultaneous tasks users have to perform, and criticality of the tasks while providing services in the wave energy generating field. Furthermore, he explained the risks associated with heavy lift work at sea and diving operations. In addition, the he mentioned the decent seakeeping ability required for special personnel on board who are not used to extended periods at sea such as maintenance engineers and technical supervisors.

Figure 6.10: HCD champion and team members of T7 and T8 having discussions with the end-user representative – Master mariner. (Picture used with consent)

Reflections: Throughout all the 'designers meet end-users' sessions, I saw the interest and the eagerness that the students showed to arrange such sessions and to have discussions with their end-user representatives. Since these sessions were arranged as the students requirement arose, I found it a student-centred approach to customise the scaffolding sessions to be user-centred. The students were well prepared with preliminary drawings and most of them had done substantial research before attending these sessions because they knew the importance of meeting an end-user to walk through their designs. This was a valuable and rare opportunity, especially for the teams whose designs were related to submarine operations because they knew the difficulty of finding an end-user representative who worked on a submarine. Thus, they tried to take the maximum from their sessions.

Another major reflection from the 'designers meet end-users' sessions was regarding the students low level understanding about the CoU of their designs. Almost none of students who were enrolled in this degree program have experience working on board ships as most of them had started their degrees straight out of school. As a requirement in one of the undergraduate units, in order to perform technical activities, such as sea trials, loading condition and stability criteria calculations and trawling activities, they go on board the AMC's training vessel for a short voyage, this being their only onboard experience. Thus, it is not possible to expect them to have sufficient knowledge on users and their tasks, and detailed working conditions of ships.

Overall summary after the modified scaffolding program

After completing this action cycle, I see the following salient facts that are practical evidence of the improvements from cycle 1:

- Added scenario during the onboard activities provided the students more opportunities than cycle 1 to understand the HF issues within the ship designs and practically experience the importance of the HCD approach

- None of the students used the label ‘common sense’ to dictate the best compromise between comfort and efficiency
- None of the students gave answers like ‘let them wear safety shoes’ or ‘out visual labels, alarms or announcements out’ as seen in cycle 1
- The HCD champions showed more engagement during the scaffolding program than their predecessors and it was gradually increasing throughout the program
- Not only the HCD champions, but also the team members, showed their enthusiasm in finding relevant videos and other useful techniques to stimulate their CoU knowledge
- Attendance of the HCD champions was improved compared to cycle 1
- Team members’ attendance and their engagement with experienced seafarers during the guest lecture sessions were also improved in this cycle
- As a result of arranging ‘designers meet end-users’ sessions according to student requirements, the HCD champions and team members effectively made the of most of end-user representatives’ knowledge to improve their own knowledge of understanding and specifying the CoU
- As a result of giving improved student-centred facilitation, motivation, and guidance, the HCD champions stayed within their group, promoting group interaction and providing suitable assistance to learn and practice the HCD approach within the design more effectively than first action cycle

6.2.6 Interview with HCD champions, internet questionnaire to team members, and review of the design project reports

Similar steps of action cycle 1 were adhered to during these data collection activities. Furthermore, the interview questions and the internet questionnaire used were also similar to cycle 1.

6.3 Data analysis and results

Data analysis method, evaluating tools, and the analysis procedure followed during this phase were similar to cycle 1.

6.3.1 Results

In order to increase the clarity and conciseness of the description of this phase and to avoid repetitions within the two action cycles, the findings from the interviews with the champions, the questionnaire to the team members, and the design report reviews are organised separately. The overall summary of the findings of the two action cycles will be encapsulated and discussed in the next chapter (Chapter 7) of this thesis.

<u>6.3.1.1 Interview with HCD champions</u>

All the champions participated in individual interviews. This group of champions showed improved understanding of the HCD approach in maritime design compared to the champions in the first cycle. All of them regarded the HCD process as a valuable design approach that focused on making systems usable by applying HF and ergonomics knowledge during the design. Furthermore, they accurately explained each steps of the HCD process and description of them as stated in ISO 9241-210 as presented within the scaffolding sessions. Also, they abstracted the use of principles of the HCD process to develop a user-centred design through an iterative process. They specified the significance of involving end-user representatives throughout the design process.

> Sometime[s] we think it is just a matter of providing adequate and comfortable accommodation when we hear HCD. But, now I think we as a team, all know it is something beyond that. We must consider the users, their tasks, frequencies, demands, and risks associated with them when we analyse CoU in order to provide user-friendly design. I personally realised the super importance of getting [in] touch with experienced users during the process to understand and specify the CoU, as I do not have that knowledge. Anyway if designers do not know why we design this ship and [for] whom we design and what is their operational environment, we will not be able to design it to [be] fit for users. So this knowledge we received is absolutely necessary.
>
> —champion of T1.

They explained the benefits end-users may receive through the HCD approach as decreased stress, fatigue and inconveniences; decreased potential to make errors; reduced hazards; and increased user-satisfaction. Also, all of them pointed out the possible benefits that the ship design companies may also gain through the HCD approach that could increase the owners' satisfaction when end-users are pleased and effective within usable designs.

> If design firms can follow this exceptionally valuable concept, as consequences, they will win the reputation as well as more design contracts, because it could increase the owners' satisfaction when end-users are pleased and effective within usable designs.
>
> —champion of T4.

Also, the champions from groups T1, T4, T6 and T8 agreed that there were challenges in the HCD process and discussed the impact of those on the final design. Furthermore, they gave a few suggestions to overcome those challenges. According to the champions of T1 and T4, integrating the HCD approach into the traditional ship design spiral and changing the traditional designers' mind-set was challenging, thus limiting the application of HCD to the ship design process. They suggested including maritime HF and HCD theory and practical components into the design project unit syllabus and conducting short programs for industry naval architects to make them aware of the importance of the HCD approach to design user-friendly ships. Furthermore, they recommended short seagoing experiences for all ship designers. According to the champions of T6 and T8, including end-users into the design process was considered as a challenging task thus reducing the usable designs. They were proposing a common system where seafarers and designers meet each other and share their knowledge to design user-friendly ships. As a summary, all HCD champions demonstrated a sound knowledge of the HCD application. Four of them exhibited well-established knowledge of HCD beyond what was offered within the scaffolding sessions. Thus, according to Rubric-A (see Chapter 4, Section 4.1.5), four champions (T1, T4, T6 and T8) reached Level 4 and the other four (T2, T3, T5 and T7) champions reached Level 3.

All HCD champions were satisfied with their champion role. Also, they stated their design outcome was the result of a team effort because all team members were appreciative of, and enthusiastic to apply, the HCD approach from the beginning of the project. The champions expressed their inclination to practice the HCD approach within future ship designs. Also, they were willing to use the experience gained as an HCD champion to motivate and guide team members in their future design teams.

All the champions appreciated the effort taken to deliver the scaffolding program throughout the design project to motivate and facilitate them. They especially mentioned the influence that onboard activities and the HCD introductory lecture session had on their HCD perspective and motivation to learn and apply a maritime HCD approach. Also, all champions gave positive feedback on the student-centred knowledge dissemination approaches: the 'designers meet end-users' sessions, the mind-map and ship virtual tour approaches, and the HF success and failure stories.

6.3.1.2 Questionnaire to team members

I received 19 responses out of 20 team members and none of them were rejected since the participants gave all of the necessary information. Similar to the HCD champions, their team members' understanding about the HCD approach to maritime design also improved in this cycle. Members of three design teams (T1, T4 and T6) demonstrated a sound understanding (Level 3) of theoretical and application of HCD as presented within the scaffolding program. All of them stated the HCD approach to maritime design as a fairly new design approach, which can guide designers to incorporate end-user requirements into the design process to make the design fit for its users. They discussed the HCD process, benefits and importance of it to develop a user-centred design through iterative process.

> HCD approach to ship design is focussing on making systems usable by applying HF and ergonomics knowledge during the design. The most important thing is as designers we must know to whom we are designing for and what are the major tasks the users are going to perform. If we design user-friendly working environment, easy personal access routes for the users, then it will minimise the daily walking distance and obstructions during operation specially when performing demanding tasks. Therefore, it can reduce their stress and fatigue. Finally, it will increase the efficiency and effectiveness.
>
> —team member of T1.

The members of the other five design teams (T2, T3, T5, T7 and T8) demonstrated a moderate understanding (Level 2) about the HCD approach to maritime design. Although they demonstrated a good theoretical HCD understanding, they did not explain the use of principles of the HCD process to develop a user-friendly design.

Team members of all design teams (19 out of 20 team members) provided positive feedback on facilitation and guidance of the champions to learn new knowledge of HCD and apply it into the design process. Furthermore, they highlighted their champions' enthusiasm in integrating the HCD approach and appreciated their way of disseminating knowledge and HCD guidance materials. In addition, all team members gave positive feedback on the student-centred knowledge dissemination approaches: the 'designers meet end-users' sessions, guest lecture sessions, the mind-map and ship virtual tour approaches, and real-world examples of HF success and failure stories.

6.3.1.3 Design project report review

The design project report of team 1 (T1) exhibited Level 4 HCD integration according to Rubric-B (see Chapter 4, Section 4.1.5). None of the design teams in cycle 1 demonstrated a multiple iterative and reflective process based on the user feedback and how multiple perspectives were integrated to develop their final design. However, T1 exhibited excellent commitment to perform multiple iterations within their design.

> A large proportion of the methodology has been concerned with Human Centred Design. As maritime experience within the design team is limited, consultation with primary and secondary users ensured the design would be practical and usable. These users included clients, masters, vessel engineers and submariners. The design solutions were evaluated with respect to HF, during each iteration in order to increase the user satisfaction.
>
> —Submarine support ship design team (T1).

Examples to demonstrate this team effort to apply the HCD approach into their design are shown in Table 6.3.

Table 6.3: Brief summary of the application of the HCD approach into the design project – Team T1.

Aspect	**Brief summary and examples**
Primary users	The design was based on the requirements of the following primary users. ▪ Vessel crew (military and civilian operating crew) ▪ Submarine crew at the time of replenishment (60-90 days)
Secondary users	The design was based on the requirements of the following primary users. ▪ Maintenance engineers (special personnel) ▪ Crew of the assisting tug boats ▪ Temporary supporting staff for humanitarian aid missions or disaster relief (special personnel) ▪ Crew of the submarine rescue vessel ▪ Operators in the disabled submarine control centre
Operational requirements / tasks	The vessel was designed to accomplish: mobilisation to the position required, arriving safe and with sufficient fuel to refuel; act as a stationary base – capable of refuelling submarines and other vessels, providing the equivalent of shore power, food resupply and minor maintenance operations on the submarine; house a full complement of submariners, humanitarian aid missions or disaster relief, etc.
Design solutions	<u>For operation</u> Examples: The concept design was capable of: refuelling 14 submarines; resupplying 70 days' worth of stores to four submarines; storing replacement parts; performing major repairs; loading torpedoes; launch and recovery of submarine rescue vessel as well as ROV, etc. The vessel was designed with 10 Hydro-pneumatic submarine specialised fenders with in-hull attachment points for submarine fendering for easy operation. The design was providing access to equivalent shore-based services for moored submarines. The design was capable of assisting dead submarines using two ship-borne tugs, carrying and containing submarine armament – Helideck and hangar, etc. <u>For comfortable living</u> Examples: The design provided comfortable accommodation for 26 permanent crew, 60 submariners, temporary maintenance crew of 20 (special personnel), and temporary supporting crew of 8 for humanitarian aid missions (special personnel), following the MLC (2006) having been evaluated using HF evaluation software (HumanCAD®) (see Figure 6.11). The design included four-bed hospital with accessibility as close as possible to the aft deck helicopter hangar. Design included service elevator to mobilise stretchered patients. In addition the design included gym, computer room, training room, quiet space for stressed submariners, counselling room, etc. <u>For appropriate manoeuvring</u> Dynamic Positioning (DP2) available

Aspect	Brief summary and examples
	For secondary role capabilities of the design Reconfigurable ‘modular deck’ was outfitted as relief hospital or additional accommodation; container deck was capable of housing an 8 × 20 ft. container, which could include aid facilities or decompression chambers; submarine rescue vessel can be accommodated. For user-friendly working environment Personal access route analysis is performed(see Figure 6.12); increased corridor width in high traffic areas; adequate space within machinery, bridge and other working areas; additional lift alongside the exhaust trunk capable of moving heavy spare parts or injured personal from machinery space; separation of clean and dirty areas; bridge visibility exceed requirements set by SOLAS (IMO, 2009); etc. Seakeeping ability The bow section is designed to reduce slamming in heavy seas. A preliminary seakeeping analysis was performed.
HF guidelines	Title 3 – Accommodation, Recreational Facilities, Food and Catering – MLC (2006) Guidance notes on The Application of Ergonomics to Marine Systems – ABS (2014) Guidance notes on Ergonomic Design of Navigation Bridges – ABS (2003) Guidelines for Engine-Room Layout, Design and Arrangement (IMO, 1998)

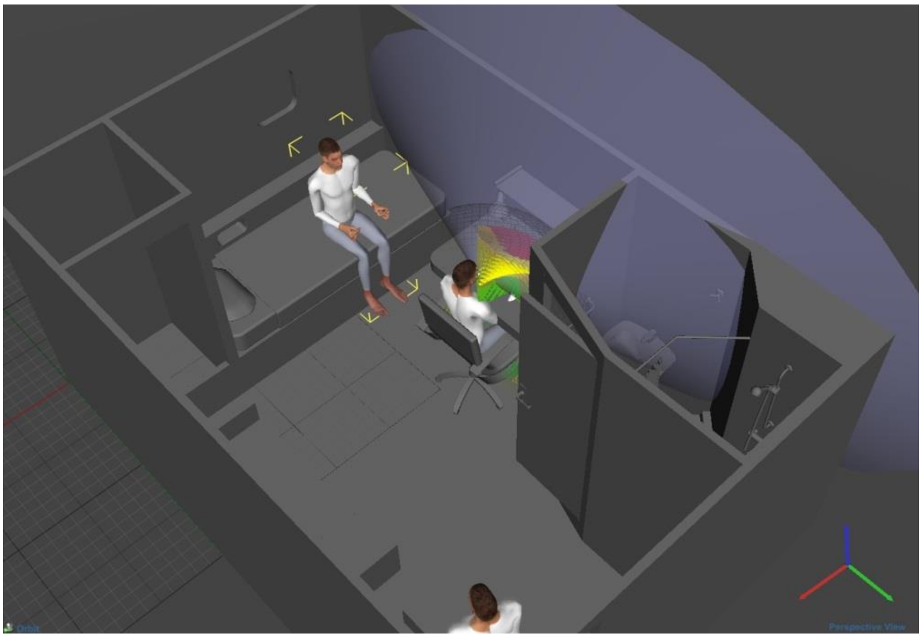


Figure 6.11: Design team T1 conducted HF evaluation of the ships’ cabin using HF evaluation software; HumanCAD®. (Picture used with consent)

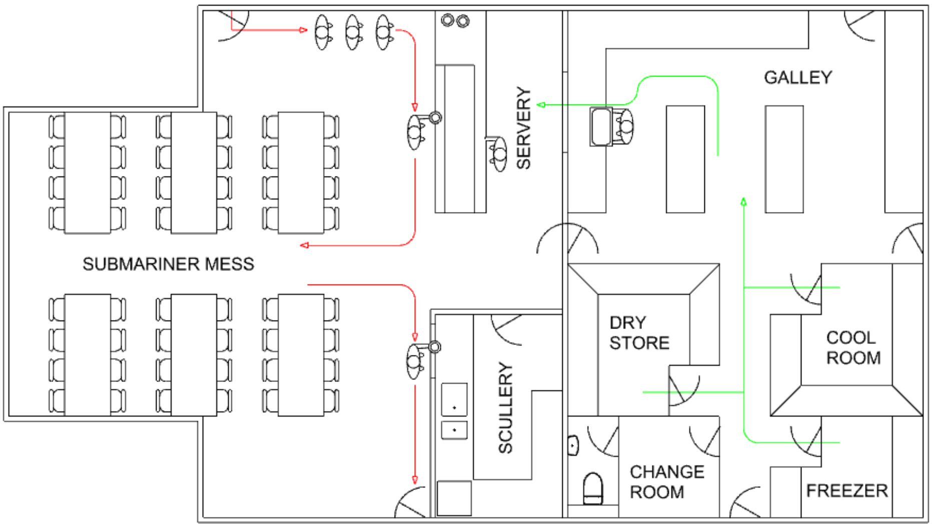


Figure 6.12: Design of the layout of mess and galley by design team T7 based on the analysis of personal access routes. (Picture used with consent)

The other teams' design reports (T2, T3, T4, T5, T6, T7 and T8) did not show the same level of commitment. However, they incorporated primary users, task-related considerations and analysis of operational scenarios as basis for their design decisions. They considered the end-user feedback to pursue user-friendly designs. In addition, they demonstrated the use of HF guidelines as one of the best practices behind their successful final designs. Thus these teams exhibited an adequate level of integration (Level 3) of the HCD approach into their designs within their design project reports. Their efforts to apply the HCD approach into the design process can be briefed as follows with a few examples (see Table 6.4).

Table 6.4: Brief summary of the application of the HCD approach into the design projects – Teams T2, T3, T4, T5, T6, T7, and T8.

Aspect	**Brief summary and examples**
Design process	HCD approach was considered during the design process by all teams. End-user representatives' feedback was incorporated by all teams.
User consideration – primary users	The conceptual designs were based on the requirements of the primary users. Examples: (1) Mobile heavy lift landing craft (T6) Vessel operator, engineer, three support crew, and 12 evacuees were considered as a basis for design decisions. (2) Submarine rescue vessel design (T2) Pilot of the rescue vessel and rescued submariners were considered as a basis for design decisions.
User consideration – secondary users	The conceptual designs were based on the requirements of the secondary users. Examples: (1) Submarine rescue vessel design (T2) Operators in the disabled submarine control centre and the mother ship control centre were considered as secondary users. (2) Passenger ferry design (T4) Port operators, large freight transporters were considered as secondary users of this vessel.

Aspect	Brief summary and examples
Operational requirements / tasks	Examples: (1) Wave energy service vessel design (T8) The vessel was designed to accomplish: safe transportation and deployment of the components of a wave energy generator assembly; towing of a buoyant actuator requiring 15 tonnes of bollard pull; diving operations; launch and recovery of ROVs and AUVs, etc. (2) Small ferry design 1 (T3) The vessel was designed to accomplish: shuttle service utilising 100% renewable energy; transportation of minimum 20 passengers. (3) Heavy lift crane barge design (T7) The vessel was designed to accomplish: carrying of the components of the wave energy converter device to the installation site and safely lower them; conducting of maintenance work with the use of ROV or divers; picking up of modules from the seafloor and transporting them to port.
Design solutions	<u>For comfortable living</u> Examples: (1) Heavy lift crane barge design (T7) A preliminary seakeeping analysis was performed and an operational window was developed for the vessel users. (2) Small ferry design 2 (T5) The design provided comfortable seating arrangement for 20 passengers, adequate legroom, special seating arrangement for a few disabled passengers, special portable lift for loading disabled passengers, one special washroom for disabled passengers, small coffee-making area for vessel crew and passengers, etc. (3) Submarine rescue vessel design (T2) Australian Royal Navy anthropometry measurements were used to design seating arrangement, escape hatches, etc. The rescue cabin was evaluated using HF evaluation software (HumanCAD®) (see Figure 6.13) (4) Wave energy service vessel design (T8) The vessel design provided comfortable accommodation for 12 permanent crew, and eight special personnel following the MLC (2006). Special personnel accommodation placed close to midships to reduce pitch motion effects and provided other facilities such as fitness centre, cinema, offices, conference room, etc. <u>For user-friendly working environment</u> Examples: (1) Passenger ferry design (T4) Taken notable effort to design easy logistical and personal access routes for their users by linking tasks and user working areas. As an example, the team analysed deckhands' personal access route by analysing his/her tasks as: arrive at work, crew meeting, prepare deck, loading procedure, organisation of vehicles, departing, crossing, berthing procedure, oversee unloading, close down service, return home. (2) Wave energy service vessel design (T8) The design process followed HF guidelines to design windows, doors, hatches, ladders, handrails, stairs (see Figure 6.14) and walkways. The design provided adequate space within machinery spaces, bridge and other working areas. (3) Small ferry design team (T3) Non-slip surfaces and grab handles were used within the design to minimise slips.

Aspect	Brief summary and examples
	For user-friendly controlling stations Examples: (1) Small ferry design team 1 and 2 (T3 and T5) This design provided a multi-functional seat for the master of their vessel. Ship controls and communication systems were designed to be equipped onto the seat's armrest and two blocks next to the marine chair. The speed control device was designed onto the left-side armrest and, also, a monitor in front of it can display general engine information. The other side armrest equipped with the electrical steering wheel to replace the traditional one on board. This seat with the storages can be rotated 45 degrees in either direction due to the hydraulic device equipped underneath the seat (see Figure 6.15). For user-friendly maintenance Examples: (1) Wave energy service vessel design (T8) The machinery space of this design provided enough servicing room for the engineers to carry out their daily checks and maintenance. (2) Heavy lift crane barge design (T7) Clean and dirty areas were separated within the design. In addition, all machineries in the engine room were arranged with 360° access. Workshops in the engine room were designed and equipped with additional equipment, such as ultrasonic cleaner and lifting devices, to further support maintenance. For appropriate manoeuvring Examples: (1) DP2 was available within the designs of T7, T8. (2) The design of Passenger ferry (T4) equipped bow and stern thrusters to improve manoeuvrability.
HF guidelines	All teams used the following HF guidelines as best practice within the designs: Title 3 – Accommodation, Recreational Facilities, Food and Catering – MLC (2006) Guidance notes on The Application of Ergonomics to Marine Systems – ABS (2014) Guidance notes on Ergonomic Design of Navigation Bridges – ABS (2003) Guidelines for Engine-Room Layout, Design and Arrangement (IMO, 1998)

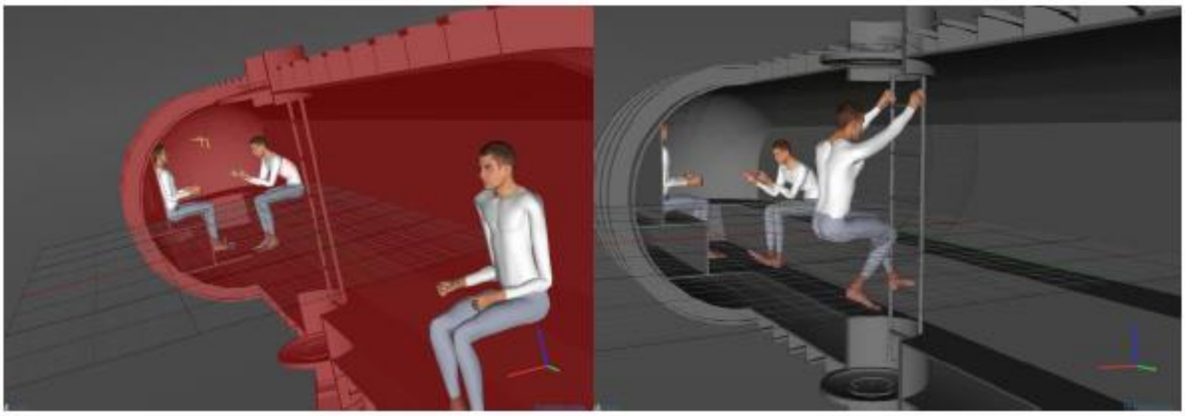


Figure 6.13: Design team T2 conducted HF evaluation of the rescue cabin using HF evaluation software; HumanCAD®. (Picture used with consent)

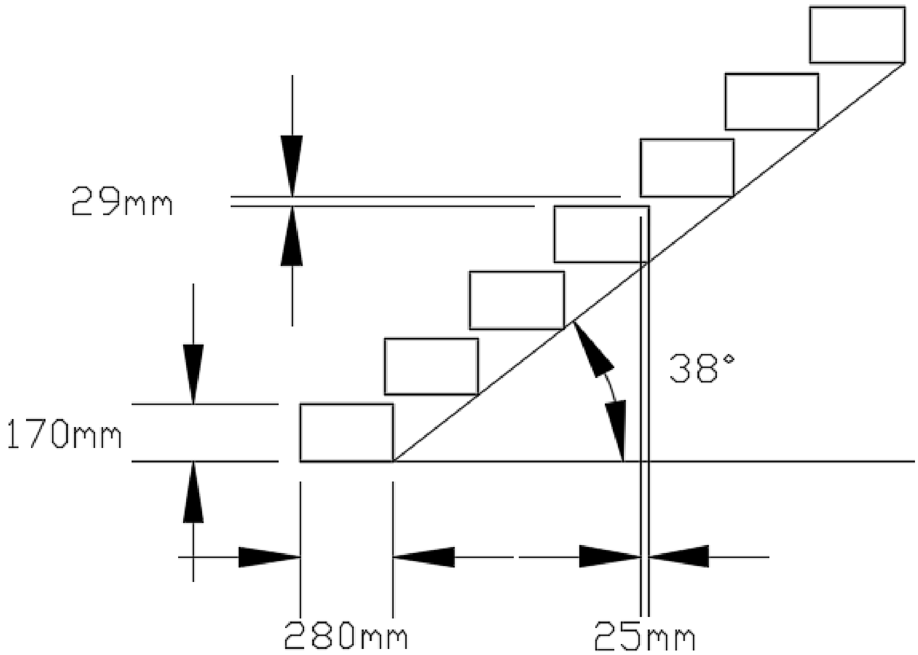


Figure 6.14: Design team T8 designed stairs and landing spaces complies with HF guidelines. (Picture used with informed consent)

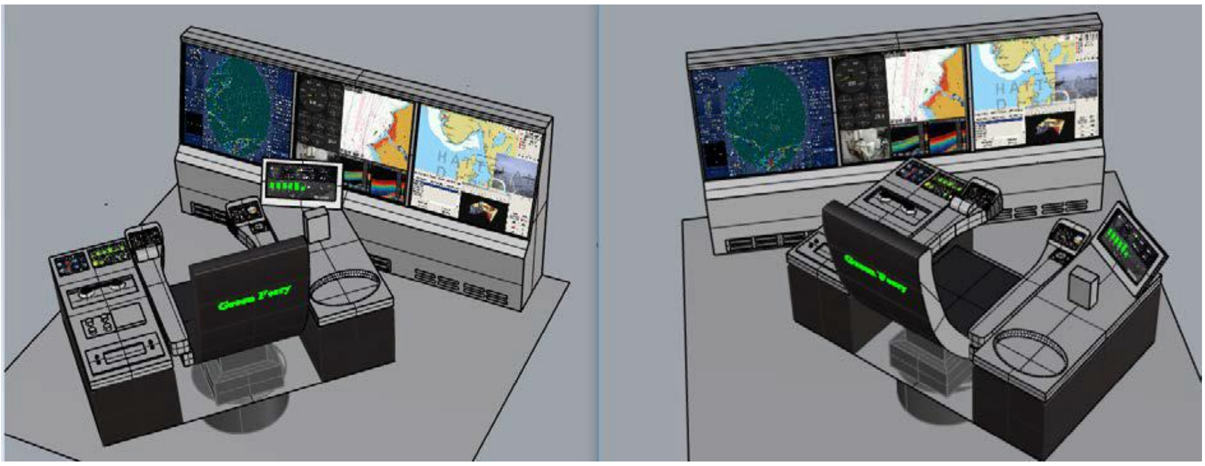


Figure 6.15: Design team T3 and T5 designed multi-functional seat for the operators of the vessel considering user needs. (Picture used with consent)

Chapter 7

Discussion and conclusion

The final chapter of this dissertation firstly provides a brief overview of the study. It then summarises the main findings, discusses the findings and the quality and validity of the study, provides conclusions, contributions, and recommendations for future research.

7.1 Overview of the study

To ensure that a ship design is appropriate for the intended purposes and for the context in which it will be used, the design process should include Human Factors (HF) through a Human Centred Design (HCD) approach (Earthy & Sherwood Jones, 2010; Lützhöft, 2004). Many maritime designers however have given little or no attention to the inclusion of HF considerations in ship design (Mallam, 2016; Walker, 2011). Similarly, maritime design education has tended to focus on the technical aspects of design and not on the provision of awareness and understanding of HF, HCD, and the operational needs of onboard crew (Abeysiriwardhane et al., 2014; Kuo & Houison-Craufurd, 2000; Myles, 2016). This has made it difficult to convey the significance of HCD and the usability mind-set to designers (Petersen, 2012). Early intervention during maritime design education is therefore essential as a first step towards increasing the inclusion of HF in future ship designs. The published literature also lacks studies about efforts to integrate HCD knowledge into maritime design education.

When considering the humanistic side of engineering education, it has been identified that design project activities are an effective pedagogical strategy for providing a frame within which an instructor can integrate essential non-technical knowledge (Fila et al., 2014). Similar to other engineering courses around the world, maritime education also considers design project activities as a significant part of their courses (Thomas et al., 2013). Therefore, it has been recognised that, if maritime students are to be introduced to maritime HF issues as well trained in the application of an HCD approach, putting that knowledge into practice during their design projects would be optimal. This eventually could ensure that graduates are equipped to enter into the workforce with a wider range of skills for designing ships that are truly ‘usable’. It was also recognised that students should be trained to carry their newly acquired HCD knowledge and experience forward into future design teams so that these concepts can be introduced to the future of maritime design.

This study constructed a pedagogical framework by connecting Peer-Led Team Learning (PLTL) pedagogy with a Problem-Based Learning (PBL) based maritime design project unit, in conjunction with associated theoretical foundations of both pedagogies; Vygotsky’s Zone of Proximal Development (ZPD) theory and the scaffolding concept. The framework contains three parties: peer leaders, design project team members, and facilitators. Following PLTL pedagogy, peer leaders are students from each design project team who act as mentors within a team. This study calls these peer leaders ‘HCD champions’. Design project team members are students working with HCD champions within a PBL environment. Facilitators are the researcher, maritime HF specialists, and experienced seafarers. Within this framework, HCD knowledge dissemination flows from facilitators to HCD champions, and then through to team members (Abeysiriwardhane et al., 2016a).

Action Research (AR) has been used as the methodological framework to study the effectiveness of the teaching framework and the HCD knowledge dissemination activities. Maritime design undergraduates who enrolled in the PBL-driven design project unit at the Australian Maritime College (AMC) were chosen as participants of this study. The first cohort, consisting of eight design teams, was facilitated through the HCD knowledge dissemination activities during the yearlong action cycle 1, in the academic year of 2015. The overall effect of the program was determined through an analysis of: records kept in a researcher’s journal, data from questionnaires and, interviews, and design project reports. The initial plan was revisited and revised in the light of the findings of the first action cycle, and the cyclic process was repeated in action cycle 2, in the academic year of 2016, with a second cohort of participants, also made up of eight design teams.

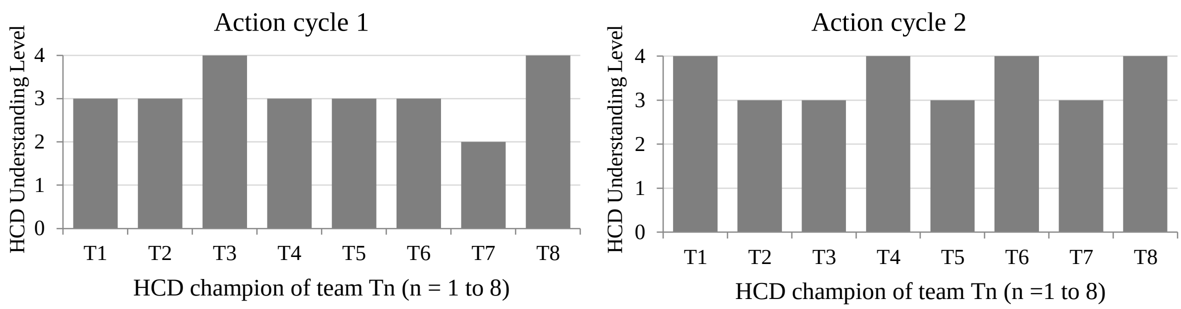
7.2 Summary of findings

<u>The HCD understanding of HCD champions</u>

- At the commencement of this research study, it was confirmed through a questionnaire that none of the HCD champions had been exposed to any maritime HF related topics during their undergraduate studies, and that they were not fully aware of HF, HCD, and onboard operational issues (Abeysiriwardhane et al., 2014). The maritime HCD understanding of the champions prior to this study is therefore graded as a lack of understanding (level 0), based on the levels elaborated in rubric-A; the HCD understanding scale (see Chapter 4, page 54).
  (Level 0 – Lacks understanding, Level 1 – Basic understanding, Level 2 – Moderate understanding, Level 3 – Sound understanding, Level 4 – Excellent understanding)

- HCD knowledge dissemination activities within action cycle 1 were effective for elevating all eight champions' HCD understanding to level 2 or higher; with two champions at level 4, five champions at level 3, and one champion at level 2.

- HCD knowledge dissemination activities within action cycle 2 were more effective than the first. The HCD understanding of the second cohort of champions was elevated to level 3 or higher; with four champions reaching level 3 and four champions level 4. A comparison of the results is illustrated in Figure 7.1.



7.1 (a) 7.1 (b)

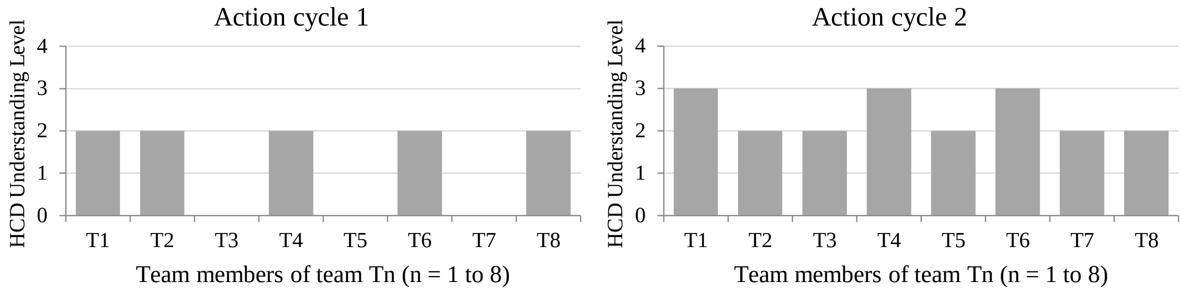
Figure 7.1: The HCD understanding level of HCD champions. (a) Upon completion of first action cycle; (b) Upon completion of second action cycle.

<u>The HCD understanding of team members</u>

- Similar to the HCD champions, at the commencement of this study none of the team member students had been exposed to any maritime HF related topics during their undergraduate studies, and they were not aware of HF, HCD, and onboard operational issues. Thus, the maritime HCD understanding of team members is graded as a lack of understanding (level 0), based on the levels elaborated in rubric-A.

- After action cycle 1, the HCD understanding of 21 team members improved to level 2, and nine team members remained at level 0. Three team members did not respond to the questionnaire.

- After action cycle 2, the HCD understanding of 12 team members improved to level 3, and seven team members to level 2. None of them remained at level 0. One team member did not respond to the questionnaire. Comparison of the results is illustrated in Figure 7.2.



7.2 (a) 7.2 (b)

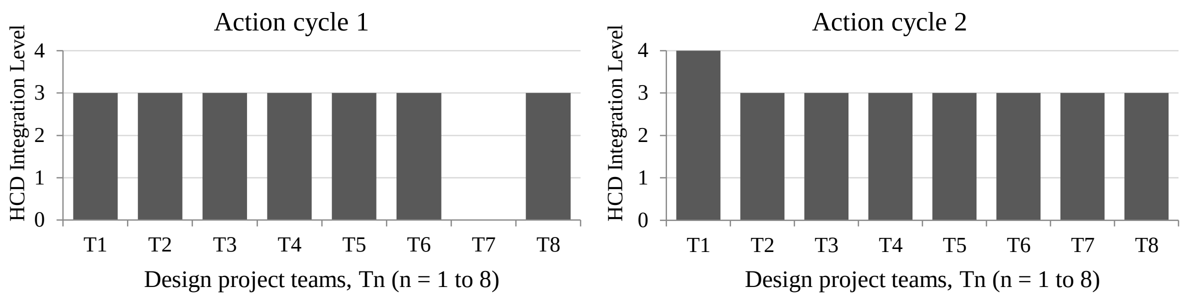
Figure 7.2: The HCD understanding level of team members. (a) Upon completion of first action cycle; (b) Upon completion of second action cycle.

<u>**HCD integration into the design projects**</u>

- A review of seven concept design reports of previous undergraduate groups at AMC (academic year 2013 and 2014), recognised that the design reports lacked maritime HCD integration. Thus, at the commencement of this study, the level of HCD integration into design projects was graded at level 0, based on the levels elaborated in rubric-B; the HCD integration scale (see Chapter 4, page 55).
  (Level 0 – Lacks integration, Level 1 – Elementary integration, Level 2 – Developing integration, Level 3 – Adequate integration, Level 4 – Excellent integration)

- After action cycle 1, seven out of the eight teams showed level 3 HCD integration into their projects. One design team remained at level 0. None of them showed level 4 HCD integration into their projects.

- Action cycle 2 brought all eight teams to a level equal to or above level 3 HCD integration. One design team showed level 4 HCD integration into their project. A comparison of results between the two action cycles is illustrated in Figure 7.3.



7.3 (a) 7.3 (b)

Figure 7.3: Level of application of the HCD approach into design projects. (a) Upon completion of first action cycle; (b) Upon completion of second action cycle.

- Findings from interviews with champions, as well as questionnaires to team members were linked with the findings of design project report reviews, and the following results apply to both action cycles.
    - Design project reports demonstrated an improved level of HCD integration when team members acknowledged the significance of an HCD approach and followed their HCD champion's facilitation and guidance throughout the design process.
      (T1, T2, T4, T6, and T8 of action cycle 1 and all design teams of action cycle 2)
    - Design reports still exhibited an improved level of HCD integration solely through the HCD champion's individual effort, even when team members did not acknowledge the significance of an HCD approach, but did not resist the process.
      (T3 and T5 of action cycle 1)
    - Design reports lacked HCD integration when the HCD champion was less competent involved in guiding and facilitating team members, and team members did not acknowledge the significance of an HCD approach in the design process.
      (T7 of action cycle 1)

<u>The HCD knowledge dissemination activities and other highlights</u>

- On completion of this study, the following HCD knowledge dissemination activities were recognised as effective pedagogical strategies for elevating student HCD understanding, as well as encouraging students to learn more about maritime HF and HCD:
    - Short seagoing training
    - HF-related onboard activities
    - Real-world examples of HF and HCD failure and success stories within ship design
    - Interactive HCD discussion sessions
    - Guest lectures from experienced seafarers, and other subject matter experts from special maritime fields such as offshore and defence
    - A 'designers meet end-users' workshop allowed students to involve feedback from end-users or end-user representatives in their design process
    - Learning tools such as mind-maps and online virtual tours of ships which were used to visually organize maritime HF and HCD information, including through videos, articles, and pictures

- The following changes made to HF-related onboard activities in action cycle 2 proved to be helpful in changing student viewpoints about maritime HF and the HCD approach as being merely 'common sense':
    - An added scenario to the evacuation activity
    - Allocation of a considerable amount of time during the activities to discuss the real practical difficulties that seafarers face due to designer's 'uncommon' common sense
    - Providing students with opportunities to interview crew onboard in order to get to know their daily tasks, the frequencies of these and their demands, and issues that they face while performing tasks

- HCD champions and team members more effectively integrated the knowledge of the end-user representatives during action cycle 2, compared to action cycle 1. This was a result of efforts taken to arrange individual ‘designers meet end-users’ sessions with each design team at different stages, whenever the teams had become ready to consult with end-user representatives.

- HCD champions mentored the group more effectively during action cycle 2 compared to action cycle 1, promoting group interaction and providing assistance. This was a result of the impact of HCD knowledge dissemination activities delivered in action cycle 2 as well as improved motivation and supervision given to HCD champions by the researcher.

- Most promisingly, according to interview and questionnaire findings, a total of 29 students from the first cohort (out of 41 students) and a total of 27 from the second cohort (out of 28 students) stated that they would use HCD within their future maritime designs.

- At the end of this research study, all 16 HCD champions, and 40 out of 53 team members suggested that they would like for maritime HF and HCD theoretical sessions as well as related practical sessions to be included into the design project syllabus as a compulsory component.

7.3 Discussion

The findings of this research study show the practicality and usefulness of applying Vygotsky’s ZPD theory (Vygotsky, 1978) and the scaffolding concept (Bruner, 1975; Wood et al., 1976) to PBL-driven design projects in maritime education in order to integrate essential non-technical knowledge into a technically-oriented study programs. In addition, they show the feasibility and effectiveness of connecting PLTL pedagogy (Gosser et al., 2001) with such design projects, in order to train selected maritime design undergraduates as peer-leaders to influence and guide others and spread their knowledge into future design teams so as to create a positive effect on future designs.

Through this pedagogical connection, scaffolding and guidance provided by more knowledgeable others (i.e., facilitators in this study), helped peer-leaders (i.e., HCD champions in this study) reach their potential ZPD levels of maritime HCD understanding. Learning took place within the ZPD, under scaffolding and collaboration with facilitators, and HCD champions were able to learn new knowledge, become aware of new issues and provide solutions for them that they could not solve easily on their own. The facilitation and guidance provided by HCD champions then helped their team members in reaching ZPD level of HCD understanding. This connection enabled team members to achieve goals and solve problems that they could not have solved on their own, without the help and guidance of HCD champions.

The HCD knowledge dissemination activities - scaffolding program - delivered in action cycle 2, based on lessons learned from action cycle 1, improved the growth of the ZPD potential of champions as well as that of team members by increasing the distance between their initial understanding of HCD and the level of the ZPD upon completion of scaffolding. According to Vygotsky: ‘the ZPD today will be the actual development level tomorrow’ (Vygotsky, 1978, p. 87). At the end of the study, therefore the students’ level of HCD knowledge eventually became their new level of independent understanding and a foundation for future learning when they enter the workforce as design engineers (see Figure 7.4). This is supported by the majority of HCD champions and team members, who expressed their willingness and intention to apply the HCD approach to future designs. In addition, they displayed an interest in learning more about this discipline in depth in the future. There were however, HCD champions and team members who did not show an 'Excellent' level of HCD understanding. The findings of the second action cycle therefore could be used to modify the scaffolding program to improve it further. This reflects the nature of AR - a spiral of continuous improvement.

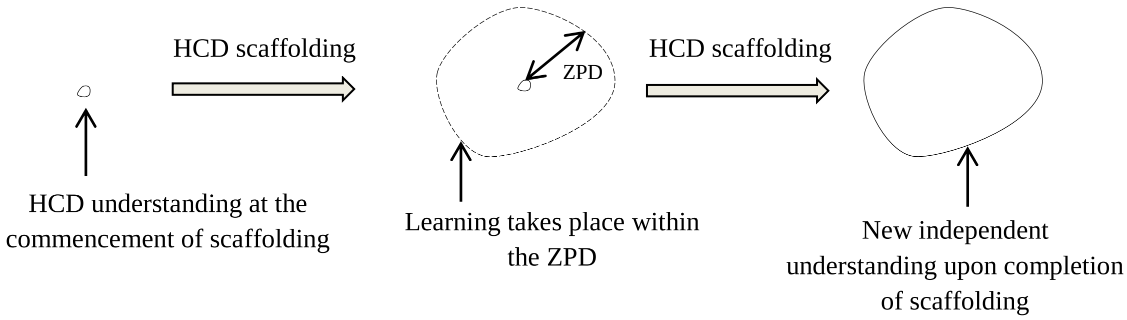


Figure 7.4: Scaffolding the learners from their initial understanding to ZPD potential to new independent understanding.

Although the ultimate goal of PLTL programs is to serve and support fellow students, the power and potential of such also lies in the benefit to those students serving in leadership roles (Gafney & Varma-Nelson, 2007; Gosser et al., 2001; Shook & Keup, 2012; Snyder & Wiles, 2015). This approach can strengthen skills such as self-direction, leadership, oral communication, intercultural skills, civic engagement, teamwork, and critical thinking abilities that have been identified as twenty-first century learning objectives for college, and that are also highly desirable skills among employers (Harmon, 2006; Shook et al., 2012).

The findings of this research study demonstrated the shared benefits gained by both parties – HCD champions serving in peer leader roles as well as team members. HCD champions were trained under facilitators and worked collaboratively with facilitators in order to support and guide their team members. They helped team members engage with the HCD materials, workshops, guest lectures, and with each other; and in this way, they supported them in building commitment and confidence in the new knowledge, making an important transition. In return, HCD champions received the opportunity to improve their skills as mentioned in above paragraph, and gained contextual teaching experience by assisting their peers.

However, action cycle 1 of this study showed less instructive effects of HCD champion interaction with team members compared to action cycle 2. It was identified that the team members who remained with a lack of HCD understanding had considered HCD 'common sense', and did not want to integrate it into their designs (Abeysiriwardhane et al., 2017). The interaction they had with champions had not been able to encourage them to abandon that mind-set. This is in line with the findings of Tudge (2000) who studied the effect of competence and confidence in peer interactions. He found that highly competent peers could seem less confident during peer interaction, and may have difficulty convincing other students. He also found conversely that peer interactions could actually deteriorate if one or more team members were less confident or expended little effort. Therefore, according to Tudge (2000), the results of action cycle 1 demonstrates the effect of competence and confidence of both parties within peer interaction.

When recruiting peer leaders (i.e., HCD champions in this study), Gosser et al. (2001) suggests to invite students who have done well in the same or a similar activities, that is, those who are well trained and supervised in facilitating small-group collaborative sessions, in order to improve the impact of PLTL approach. However, it was impossible to invite such students in this case, since the HCD scaffolding program had not been delivered to students at AMC in previous years. This might be one explanation for the lower confidence of the champions during peer interaction in action cycle 1. Even when one year of training was completed in action cycle 2, it was challenging to retain HCD champions to participate further. Most of them were keen to work immediately in the industry when they graduated.

To improve this situation during action cycle 2 therefore, I invited the design project teams to discuss among themselves and select a student that they all agreed on to become their HCD champion. This proved helpful for improving the HCD champion's interaction with their team members. Furthermore, the improved motivation and supervision that was provided to the champions, as well as to team members during the HCD knowledge dissemination activities was found to also be effective. As a result the HCD champions in action cycle 2 scaffolded 19 team members out of 20 to level 2 or higher HCD understanding. This was in contrast to the first cycle, where 21 out of 33 who went to level 2, while nine remained at level 0 and three members did not respond.

During action cycle 2, when the interaction of HCD champions with team members was stronger than the previous cycle, the team effort to integrate HCD into their design projects was also greatly improved. None of the teams exhibited a lack of HCD integration during action cycle 2. This clearly shows the significance of collaboration and coordination among team members for developing improved HF integrated designs. Koutsikouri et al. (2008) have explained the importance of interaction between individuals in successful design projects. According to them, the three dimensions of success in any project are cost, time and team success, or the outcomes of team work. For instance, even if the project fails in terms of meeting basic standards such as cost and time, the project may still be a success in terms of team work. Team effort is thus an important project objective. Throughout the scaffolding program of action cycle 2, HCD champions were requested to keep team-work attributes in mind, and this may have had an impact on the improved level of HCD integration into their designs.

Many researchers highlight the importance of practical training within engineering education (Le & Tam, 2008; Rompelman & De Vries, 2002; Zhang & Zhang, 2011). It can directly affect an individual's learning, and has many benefits such as familiarising students with a practical engineering working environment which can also provide a taste of real situations (Magoha, 2002). It can also connect theory to the practical situations, and equip them with the necessary understanding to be job ready when they graduate (Kabouridis et al., 2014; Zhang et al., 2011). In maritime design education, Kuo et al. (2000), The Nautical Institute (2015), and Petersen (2012) have suggested the introduction of practical methods such as seagoing training to motivate ship designers to follow non-technical matters and end up with usable designs. Petersen (2012, p. 187) stresses that 'engineers are inherently practical people. Do not lecture. Shut up, and engineer'. However, these authors did not investigate their suggestion practically with maritime design undergraduates. The present research study followed up on this suggestion, validated it, and demonstrated the influence that even short seagoing training and HF-related onboard activities can have on maritime HF and HCD awareness and understanding among students, in order to help them produce user-friendly design proposals.

The challenges that the students experienced during onboard activities also provided them with valuable insight and a better understanding of the practical aspects of use, and the importance of HCD for seafarer life. They also learned the importance of HCD knowledge for designing usable ships. The profound influence that these onboard activities had therefore was clearly demonstrated in all the concept design proposals completed by the students. The reports provided solutions for issues that students faced during the onboard activities; evacuation of an injured person from machinery space to the main deck, checking the accessibility/operability of valves available in machinery space and on the main deck, checking space utilization in accommodation and recreation spaces, and carrying provisions from the main deck to stores, then on to the galley, and finally to the garbage station (Abeysiriwardhane et al., 2017). As an example, students analysed logistical and personal access routes and tried minimising walking distances from mess to stores, loading bay to stores, and loading bay to mess, and they provided adequate provision loading and transfer facilities.

Although seagoing training is a promising way of enhancing student HF and HCD understanding and awareness, facilitators must plan HF-related onboard activities carefully by paying attention to the objectives of the training - to familiarise them with the onboard operational environment, its users, the related tasks and their frequencies and demands, allowing them to practically experience HF issues. After completing these activities students should be able to provide meaningful and practical suggestions for HCD improvements and be able to understand and specify context of use.

The 'designers meet end-users' workshops also had a great impact on student HCD understanding, especially for stimulating the context of use knowledge. HCD champions and team members effectively absorbed end-user representative knowledge and improved designs based on their feedback. As future designers, they experienced how end-users can provide valuable input on workplace processes, tasks, equipment, and potential risks which designers should consider during the process of ship design. Furthermore, they learned how user feedback can inform designers of both the good features to be continued and developed, and the failures and weaknesses to be discontinued. This research study thus exhibits the value of setting up a common stage for seafarers and future designers to meet, so that an HCD approach can be incorporated into the ship design process (Abeysiriwardhane et al., 2016b).

At the end of two years of this AR study, the findings highlight the benefits of utilising multiple approaches of knowledge dissemination in order to elevate the HCD understanding of students, as well as to encourage them to acquire new knowledge. Adding visual and sensing learning techniques (Cooperstein et al., 2004) such as pictures, videos, real-world examples, and charts to the traditional teaching process helped the HCD champions and team members:

- Make abstract ideas of HCD visible and concrete
- Provide structure for thinking, discussing and planning HCD processes
- Focus thoughts and ideas that lead to understanding and interpreting maritime HF and HCD

As an illustration, presenting real-world cases helped to improve student engagement within the class (Cooperstein et al., 2004; Haack, 1972), it assisted their argumentation skills (Shulman, 1987), and motivated them to find more examples related to the topic discussed. This is supported by several authors. According to Felder and Silverman (1988) and Duffy et al. (1993) using real-world examples as teaching strategies in the classroom can make learning about important issues more meaningful to students, and it can help spark excitement in learning. In addition, it supports the value of authenticity (Felder et al., 2000). Not only does it make it more meaningful for students, but they become engaged in learning and become more aware of the choices they make in society (David Merrill, 2007; Felder et al., 2000).

This finding can be further discussed through the Felder and Silverman's (1988) model of styles in engineering learning. It is noteworthy that 'many or most engineering students are visual, sensing, inductive, and active, and some of the most creative students are global' (Felder et al., 1988, p. 680). Visual learners remember best when they see 'pictures, diagrams, flow charts, time lines, films, demonstrations,' and sensing learners like 'facts, data and experimentation' (Felder et al., 1988, p. 676). Although visual images are an integral part of human cognition, they tend to be marginalized and undervalued in the education system (McLoughlin & Krakowski, 2001; Willis et al., 2006). Lectures tend to emphasize the linguistic dimension of the learning process, which includes verbal, symbolic, and numerical representations (McLoughlin et al., 2001). Visual - non-linguistic - thinking should be a partner to linguistic ways of expressing ideas and thoughts (Willis et al., 2006).

Inductive learners need motivation. They do not feel comfortable with the 'trust me-this stuff will be useful to you someday' approach: like sensing learners, they need to see the phenomena before they can understand and appreciate the underlying theory' (Felder et al., 1988, p. 678). Within this study, activities such as seagoing training, onboard HCD exercises, 'designers meets end-users' workshops, and the guest lectures delivered within it provided motivation for learning. Guest lectures from experienced seafarers were delivered based on real work experience and thus, students could appreciate the importance of the HCD approach in the ship design process.

Active learners do not learn much in situations which require them to be passive, like the typical lecture setting (Felder et al., 1988), and it is similarly noteworthy that active learners work well in groups (Gardner, 2006a). Finally, global learners are the 'synthesizers, the multidisciplinary researchers, the systems thinkers, the ones who see the connection no else sees' (Felder et al., 1988, p. 679). Activities such as seagoing training, onboard HCD exercises, interactive HCD discussion sessions, and guest lectures provide learning support for active and global learners. As a result, active participation of HCD champions in the subject matter improved in each discussion session in classroom lectures. HCD champions as well as team members were able to articulate different points on each topic.

Several authors support the use of this 'discussion' strategy for enhancing student motivation, fostering intellectual agility, and encouraging democratic habits (Brookfield et al., 2012; Davis, 2009). According to these authors, 'discussion' pedagogical strategy creates opportunities for students to practice and sharpen a number of skills, including the ability to explore a diversity of perspectives on the topic, recognise and investigate assumptions, develop attentive and respectful listening, learn respect for others voices and experiences and develop habits of collaborative learning. Furthermore, many authors support the use of 'guest lecture' strategy to increase the efficiency of a general lecture. According to Gibbs and Habeshaw (1989), and Frederick (1986), guest lectures can vary stimulation in the lecture and break the vigilance decrement and can enrich the overall learning experience of the students. In addition, this could improve relations between university and industry (Wolfe, 2006). Through this pedagogical tool students had given opportunity to lean through real-world experiences, insights and perspectives for the particular fields and disciplines (Metrejean & Zarzeski, 2001).

Altogether the findings of this study imply that while the design engineering community is not representative of the archetypical composition of intelligences (Gardner, 2006a, 2006b), they are demanding in terms of learning preferences (Felder et al., 1988; Lützhöft et al., 2017).

AR in its nature allowed me to follow a student-centred HCD knowledge dissemination program during this research study. Student-centred learning refers to a wide variety of educational programs intended to address the distinct learning needs, interests, aspirations of individual students and groups of students (O'Neill et al., 2005). According to many studies, if education is to be truly student-centred, students should be consulted about the process of learning and teaching. This is considered an 'inside out' approach and it is believed that students who are 'inside' know what is best for them (Bates et al., 2017; Bunch, 2017; Holland, 2017; Lea et al., 2003; Sparmacher, 1950; Stefani et al., 2000). During this research study, I followed such an approach.

The feedback I received from HCD champions and their team members at the end of action cycle 1 was taken into account to modify action cycle 2. As a result, I could deliver HCD knowledge dissemination activities based on the distinct learning needs, interests, aspirations of students, and thus it influenced their understanding and awareness. For example, my observations in conjunction with student feedback regarding the 'designers meet end-users' workshop session in action cycle 2 proved the effectiveness of this 'inside out' approach.

Finally, my reflections from two consecutive years of this AR study have offered me a significant insight: that is, that there needs to be a 'change agent' (Rapoport, 1970) behind HCD champions. This realisation is based on the understanding that my actions, facilitation and collaboration encouraged the champions to become more capable peers in HCD within their design teams. As a change agent however, I needed managerial support to facilitate, motivate and encourage HCD champions. This came mainly from faculty members at AMC, a HF specialist and experienced seafarers which enabled me to carry out the work presented in this thesis in a smooth manner.

Another follow-on insight is that the HCD champions, who had managerial support from me, became 'change agents' themselves for their team members. If the HCD champions did not have support, their influence on the team could well have been much less successful. This reflection is very similar to that which Gulliksen, Boivie, and Göransson (2006) and Boivie, Gulliksen, and Göransson (2006) came to during their work on the perspectives of usability designers. According to these authors, if a usability designer wants to change an organisation or influence a team, he/she needs support from the organisation. Without that, even the first attempt at collaboration may put the usability designer under pressure (Gulliksen et al., 2006; Petersen, 2012; Zuber-Skenitt, 1993). The studies that plan to utilise the pedagogical framework and HCD knowledge dissemination activities utilised in this study need to enlist a change agent, who can provide facilitation of HCD champions to smoothly operationalize their peer leadership role.

As an overall summary, connecting PLTL pedagogy and a PBL-driven maritime design unit, in conjunction with associated theoretical foundations of PLTL and PBL; Vygotsky's ZPD theory and scaffolding approach, provided an instructive pedagogical framework that guided the integration of non-technical HCD knowledge into a technically-oriented maritime design unit. Successful HCD knowledge dissemination thought this framework encouraged future maritime designers to think about the people that they will be engineering for and within the future, which in turn led to the development of holistic maritime designers. In addition, the total effort was helpful for creating skilful and unique maritime HCD champions who can guide and influence their colleagues, and carry forward their knowledge into their future design teams.

7.4 Judging the quality and validity of the study

As explained in Chapter 4, Section 4.7, Herr and Anderson (2005) defined five means of quality in AR projects; outcome validity, process validity, democratic validity, catalytic validity, and dialogic validity. The application of those validity methods to this research study will now be discussed in this section.

Outcome validity

Outcome validity measures whether or not the action eventually was effective, and whether it brought about the change that it set out to achieve (Greenwood & Levin, 1998; Herr et al., 2005). As explained in Section 7.2 of this chapter, outcomes of this research were not confined to whether actions were effective in bringing HCD champions and their team members to a level of independent understanding of HCD, but also consideration was given to the actual application of their knowledge to design projects. Findings showed that actions were effective in improving the students' understanding of HCD and its application to their design projects. Furthermore, the improved actions during the second action cycle elevated the HCD knowledge of the champions and their team members as well as its application to their design projects much more effectively than in the first action cycle. However, improvements to actions in any future evolvements may advance outcome validity even further (Bruffy, 2012; McIntyre, 1995).

According to Mertler (2016), the researcher can and should eliminate his/her bias in the interpretation of the collected data by representing participant views in the outcomes of the research, when accomplishing outcome validity. As explained in chapter 5 and 6, results represented the voices of HCD champions and their team members rather than mine alone as a researcher. At the end of both action cycles, I invited all champions and their team members together in order to share the findings of the research study. Five HCD champions and their team members were available for the meeting in the first action cycle and seven in the second action cycle. The summary of the results, my reflections and interpretations were explained to them. This gave participants the opportunity to correct errors and challenge my interpretations. They did not show any disagreement with the results and reflections. They stated satisfaction about the levels that they reached in the HCD understanding scale, since this was the first time in their undergraduate education that they had learnt about maritime HF and HCD. However, they requested that I share with them my published work so far, which I did after the meeting. Furthermore, I emailed the summary of results to all participants of this study, hoping to further establish outcome validity for it. In addition, I shared my findings with faculty members, an HF specialist, and a few seafarers who had supported me during this study. They did not show any disagreement with the results and reflections.

Process validity

Process validity examines whether the outcome of a project can be attributed to the collaborative and reflective journey (Herr et al., 2005; McNiff, 2002). Within this research study, as described in chapter 5 and 6, process validity was fulfilled by conducting collaborative research with participants in a reflective manner. I maintained a research journal throughout the study, which enabled an enquiry-reflection process at the heart of learning (Moon, 2004). I used my research journal to reflect and to find evidence for the effectiveness of the effort taken, especially within the action implementation phase. In order to make the representation transparent, and to help the reader to be able to reproduce results along the same lines (Schön, 1983), I used quotes (for the words of the students as well as for my own) from my research diary in this thesis. I discussed the summary of my research journal with my research supervisors when we met during supervisory meetings. In addition, I shared my reflections and interpretations with participants at the end of both cycles. In order to strengthen process validity further, I utilised a variety of tools for collecting data such as interviews, questionnaires, and documentary evidence, so that data collection was not limited to only one kind of data source and to not only one type of data.

Democratic validity

Democratic validity examines the 'extent to which the research is done in collaboration with all parties who have a stake in the problem under investigation, and multiple perspective and interests are taken into account' (Herr et al., 2005, p. 56). I claim that maritime design undergraduates have a primary stake in the problem under investigation within this research study. As explained in chapter 5 and 6, HCD champions maintained close collaboration with me throughout the action implementation phase ensuring the transmission of HCD knowledge to team members. They provided authentic feedback and suggestions to improve the impact of dissemination activities for raising HCD understanding. Most of the team members also became actively involved in the study and were stimulated to reflect on the problems they faced during HCD implementation in design projects. However their association with this study was connected mainly through the HCD champions. In addition, I engaged in dialogue with them during group workshops. During this study, although I have taken into account multiple perspectives from participants, it would be possible to go even further in accomplishing democratic validity. Faculty members could have been more actively involved with this study which situated them as joint contributors and investigators of its findings.

Catalytic validity

The next quality indicator, catalytic validity, refers to the transformative potential of AR, specifically the education of both the researcher and the participants (Herr et al., 2005). Herr et al. (2005) explain that researchers should recount a spiralling change in their own understanding as well as in that of their participants, and stated that, 'This reinforces the importance of keeping a research journal in which action-researchers can monitor their own change process and consequent changes in the dynamics of the setting' (Herr et al., 2005, pp. 56-57). I maintained a research journal for the entire period of this study as a transparent and credible representation (Bullough & Pinnegar, 2001; Feldman, 2007; Heikkinen et al., 2007) of the change in understanding of both the participants and the researchers within both action cycles. Based on that, I have provided a thick description (Geertz, 1983) of my actions, findings, reflections, and modifications to the actions (see Chapter 5 and 6) so that anyone who follows this research can understand the transformation of the participants as well as the researcher.

Dialogic validity

The final quality indicator, which is dialogic validity, denotes the extent to which the research is monitored through a form of peer review (Herr et al., 2005). In order to accomplish the requirements of this indicator, my reflections, interpretations, and findings throughout the research study were reviewed with two of my research supervisors who have experience in conducting AR projects. One of them played the role of the devil's advocate in interpreting what other meanings could be derived from the results (Herr et al., 2005) and by making recommendations for moving forward. After this internal review, sections of this research study have passed through the process of peer review in academic journals and been presented at conferences and seminars attended by representatives of the maritime HF and HCD research community and the maritime field. These processes have been mostly valuable in establishing dialogic validity for this research study.

7.5 Conclusions

This thesis has addressed a practical issue, a common criticism of maritime design education, often articulated as a bias towards the technological field with a missing HCD component. It follows an academic approach to constructing and adapting a teaching framework to impart HCD knowledge into maritime design education through undergraduate design projects.

The major findings of this thesis are:

- None of the maritime undergraduates (naval architecture, marine and offshore engineering, and ocean engineering) who participated in this study had been exposed to maritime HF and HCD before the commencement of this study. Furthermore, some of them did not even acknowledge the influence of human-centred design on the life of seafarers. They suggested using common sense to design usable ship designs, which an embarrassingly defensive attitude is shown by future ship designers. Thus, it can be concluded that requirements for integrating HF and HCD knowledge into maritime design education should be addressed globally in order to prepare holistic maritime designers.

- This thesis constructed, which was then operationalised, and validated a pedagogical framework for integrating HCD knowledge into maritime design education through undergraduate design projects. The framework connected peer-led team learning (PLTL) pedagogy and problem-based learning (PBL) pedagogy based maritime design project unit, in conjunction with associated theoretical foundations; Vygotsky's zone of proximal development (ZPD) theory and the scaffolding concept. The HCD knowledge was disseminated through this pedagogical framework, and in turn led to the development of holistic maritime designers.

- The pedagogical framework and the HCD knowledge dissemination activities were tested with 69 maritime design undergraduates in two consecutive years of AR study. The total effort made a noteworthy contribution to:
  - Improving the HCD understanding of 56 of the maritime design undergraduates to a satisfactory level from an original point of a lack of understanding
  - Preparing these undergraduates to think about the people they are designing for
  - Developing skilful and unique maritime HCD champions who can guide, facilitate and influence their colleagues as well as carry forward their knowledge into future design teams

- The HCD knowledge dissemination activities listed below are identified as effective scaffolding approaches for elevating leaners HCD understanding, as well as encouraging them to acquire more about maritime HF and HCD:
    - ➢ Providing short seagoing training, and conducting HF-related onboard activities
    - ➢ Showing real-world examples of HF and HCD failure and success stories in ship design
    - ➢ Conducting interactive HCD 'discussion sessions' with students in the classroom
    - ➢ Delivering guest lectures from experienced seafarers, HF specialists, and naval architects
    - ➢ Introducing end-user representatives to students, and vice versa, by arranging 'designers meet end-users' workshops
    - ➢ Introducing methods such as mind-maps and online virtual tours of ships to visually organize maritime HF and HCD information including by videos, articles, and pictures related to their design activities

- The findings of this research show that maritime design undergraduates are demanding in terms of learning preferences, mainly visual, sensing, inductive, and active. Therefore, multiple styles of HCD knowledge dissemination helps learners to make non-concrete ideas of HCD visible and concrete, providing structure for thinking, discussing and planning the HCD process, and focusing thoughts and ideas that lead to understanding and interpreting HF and HCD. Thus, it can be concluded that these learning preferences should become partner to the traditional linguistic dimension of the teaching process which includes verbal, symbolic, and numerical representations.

- In order to meaningfully include HCD knowledge in maritime education for design undergraduates, the attitudes and traditional norms, which are biased towards the technical field, must evolve as a precondition for effective knowledge transfer. To support this, maritime educational institutions and responsible faculty members all over the world must acknowledge the significance of integrating HCD knowledge into undergraduate education, and should consider bottom-up initiatives, such as that investigated in this thesis.

7.6 Contributions

Contributions to academia:

- Academic institutions that run PBL-driven maritime design projects have an opportunity to utilise a tested and validated teaching framework and the HCD knowledge dissemination activities to integrate HCD knowledge into their maritime degree course.

- Throughout this thesis, worthwhile information and examples of planning, delivering, reflecting and re-planning of all activities through AR are offered. Furthermore, this thesis has collected a large amount of practical evidence from an insufficiently researched domain. This will help those who wish to follow in the footsteps of this research.

Contributions to the maritime domain:

- The HCD champion concept introduced in this study is a novel approach to disseminating HF and HCD concepts in the maritime domain, as the champions were trained to spread this knowledge among their colleagues. These HCD champions will be able to pinpoint the significance of these concepts for their future design teams, increasing the pace of the spread of this message as a contribution to developing user centred designs.

- Most HCD champions from the first cohort of participants are now working in the industry. When communicating with some of them, I was informed that they have already started practicing and convincing others to implement what they learned during HCD scaffolding sessions delivered.

7.7 Recommendations for future research

Direct extension of this thesis could lead to the following:

- Exercising the pedagogical framework and the HCD knowledge dissemination activities in different educational institutes which deliver PBL based maritime design projects. It could enable them to fine tune the knowledge dissemination activities based on their infrastructure facilities. It then could help other institutes in the world to identify the most suitable activities to use in their context[1].

- Including a wider cross section of stakeholders involved in a ship's lifecycle in a facilitator team. In the current study, HF specialist, experienced seafarers and naval architects facilitated students. However, if stakeholders included ship owners and managers, charterers, class surveyors and yard representatives in the team of facilitators, students could get a rare opportunity to receive feedback for their designs from different perspectives. This would enable them to experience how to cater for requirements raised by various stakeholders while satisfying their needs within the HCD process. The information provided by stakeholders must be carefully monitored however, ensuring that students achieve the learning outcomes of the design project within the given time frame.

[1] Currently, one of the leading maritime training institutions in United Kingdom, Warsash Maritime Academy, part of the School of Maritime Science and Engineering at Southampton Solent University, has shown an interest in implementing this framework to facilitate their ship science students.

Closing note

I declare the following statement and heuristics for assisting the implementation process of this study.

‘Maritime design undergraduate projects provide the basis for integrating HCD knowledge into the maritime design profession. Linking a PLTL approach with PBL design projects in conjunction with Vygotsky’s ZPD theory and scaffolding concept, offers a pedagogical framework. This framework has elevated the HCD understanding of 56 future maritime designers. This created a cohort of unique HCD champions who are trained to carry forward their knowledge into future design teams, and guide them to shape ships for people’

<u>Heuristics for communicating HCD to maritime design undergraduates/future professional designers</u>

- ✓ Heuristic 1: Are you struggling to convince maritime designers that there is something called ‘HF issues’ within ship design? Do not start with lectures, undertake onboard practical activities.
- ✓ Heuristic 2: Most of the engineering community are visual, sensing, inductive, and active. Thus, knowledge dissemination activities should include these representations of knowledge to complement traditional teaching.
- ✓ Heuristic 3: End-user inclusion in the maritime design process is critical to the success of design. Thus, end-user involvement during knowledge dissemination is vital.

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Appendix A

Approval documents from Human Research Ethics Committee (Tasmania)

Social Science Ethics Officer
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Katherine.Shaw@utas.edu.au

29 July 2014

Professor Margareta Lutzhoft
Seafaring
Private Bag 1397

Dear Professor Lutzhoft

Re: MINIMAL RISK ETHICS APPLICATION APPROVAL
Ethics Ref: H0014268 - Impact of human factors in shipping across the design and operational lifecycle

We are pleased to advise that acting on a mandate from the Tasmania Social Sciences HREC, the Chair of the committee considered and approved the above project on 29 July 2014.

This approval constitutes ethical clearance by the Tasmania Social Sciences Human Research Ethics Committee. The decision and authority to commence the associated research may be dependent on factors beyond the remit of the ethics review process. For example, your research may need ethics clearance from other organisations or review by your research governance coordinator or Head of Department. It is your responsibility to find out if the approval of other bodies or authorities is required. It is recommended that the proposed research should not commence until you have satisfied these requirements.

Please note that this approval is for four years and is conditional upon receipt of an annual Progress Report. Ethics approval for this project will lapse if a Progress Report is not submitted.

The following conditions apply to this approval. Failure to abide by these conditions may result in suspension or discontinuation of approval.

1. It is the responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval, to ensure the project is conducted as approved by the Ethics Committee, and to notify the Committee if any investigators are added to, or cease involvement with, the project.

2. Complaints: If any complaints are received or ethical issues arise during the course of the project, investigators should advise the Executive Officer of the Ethics Committee on 03 6226 7479 or human.ethics@utas.edu.au.

3. Incidents or adverse effects: Investigators should notify the Ethics Committee immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.

4. Amendments to Project: Modifications to the project must not proceed until approval is obtained from the Ethics Committee. Please submit an Amendment Form (available on our website) to notify the Ethics Committee of the proposed modifications.

5. Annual Report: Continued approval for this project is dependent on the submission of a Progress Report by the anniversary date of your approval. You will be sent a courtesy reminder closer to this date. **Failure to submit a Progress Report will mean that ethics approval for this project will lapse.**

6. Final Report: A Final Report and a copy of any published material arising from the project, either in full or abstract, must be provided at the end of the project.

Yours sincerely

For Ethics Officer
Tasmania Social Sciences HREC

Social Science Ethics Officer
Private Bag 01 Hobart
Tasmania 7001 Australia
Tel: (03) 6226 2763
Fax: (03) 6226 7148
Katherine.Shaw@utas.edu.au

HUMAN RESEARCH ETHICS COMMITTEE (TASMANIA) NETWORK

11 September 2014

Professor Margareta Lutzhoft
Seafaring
Australian Maritime College
Locked Bag 1397

Student researcher: Hettiarachchige S Apsara Abeysiriwardhane

Sent via email

Dear Professor Lutzhoft

Re: MINIMAL RISK ETHICS APPLICATION APPROVAL
Ethics Ref: **H0014412 - Impact of human factors in shipping across the design and operational lifecycle**

We are pleased to advise that acting on a mandate from the Tasmania Social Sciences HREC, the Chair of the committee considered and approved the above project on 9 September 2014.

This approval constitutes ethical clearance by the Tasmania Social Sciences Human Research Ethics Committee. The decision and authority to commence the associated research may be dependent on factors beyond the remit of the ethics review process. For example, your research may need ethics clearance from other organisations or review by your research governance coordinator or Head of Department. It is your responsibility to find out if the approval of other bodies or authorities is required. It is recommended that the proposed research should not commence until you have satisfied these requirements.

Please note that this approval is for four years and is conditional upon receipt of an annual Progress Report. Ethics approval for this project will lapse if a Progress Report is not submitted.

The following conditions apply to this approval. Failure to abide by these conditions may result in suspension or discontinuation of approval.

1. It is the responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval, to ensure the project is conducted as approved by the Ethics

Committee, and to notify the Committee if any investigators are added to, or cease involvement with, the project.

2. Complaints: If any complaints are received or ethical issues arise during the course of the project, investigators should advise the Executive Officer of the Ethics Committee on 03 6226 7479 or human.ethics@utas.edu.au.

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4. Amendments to Project: Modifications to the project must not proceed until approval is obtained from the Ethics Committee. Please submit an Amendment Form (available on our website) to notify the Ethics Committee of the proposed modifications.

5. Annual Report: Continued approval for this project is dependent on the submission of a Progress Report by the anniversary date of your approval. You will be sent a courtesy reminder closer to this date. **Failure to submit a Progress Report will mean that ethics approval for this project will lapse.**

6. Final Report: A Final Report and a copy of any published material arising from the project, either in full or abstract, must be provided at the end of the project.

Katherine Shaw
Executive Officer
Tasmania Social Sciences HREC

Social Science Ethics Officer
Private Bag 01 Hobart
Tasmania 7001 Australia
Tel: (03) 6226 2763
Fax: (03) 6226 7148
Katherine.Shaw@utas.edu.au

HUMAN RESEARCH ETHICS COMMITTEE (TASMANIA) NETWORK

20 March 2015

Professor Margareta Lutzhoft
Seafaring
Locked Bag 1397

Student Researcher: Apsara Abeysiriwardhane

Sent via email

Dear Professor Lutzhoft

Re: MINIMAL RISK ETHICS APPLICATION APPROVAL
Ethics Ref: **H0014771 - Impact of human factors in shipping across the design and operational lifecycle**

We are pleased to advise that acting on a mandate from the Tasmania Social Sciences HREC, the Chair of the committee considered and approved the above project on 20 March 2015.

This approval constitutes ethical clearance by the Tasmania Social Sciences Human Research Ethics Committee. The decision and authority to commence the associated research may be dependent on factors beyond the remit of the ethics review process. For example, your research may need ethics clearance from other organisations or review by your research governance coordinator or Head of Department. It is your responsibility to find out if the approval of other bodies or authorities is required. It is recommended that the proposed research should not commence until you have satisfied these requirements.

Please note that this approval is for four years and is conditional upon receipt of an annual Progress Report. Ethics approval for this project will lapse if a Progress Report is not submitted.

The following conditions apply to this approval. Failure to abide by these conditions may result in suspension or discontinuation of approval.

1. It is the responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval, to ensure the project is conducted as approved by the Ethics Committee, and to notify the Committee if any investigators are added to, or cease involvement with, the project.

2. Complaints: If any complaints are received or ethical issues arise during the course of the project, investigators should advise the Executive Officer of the Ethics Committee on 03 6226 7479 or human.ethics@utas.edu.au.

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6. Final Report: A Final Report and a copy of any published material arising from the project, either in full or abstract, must be provided at the end of the project.

Yours sincerely

Katherine Shaw
Executive Officer
Tasmania Social Sciences HREC

Appendix B

Classroom questionnaire

Instructions

This questionnaire can be completed in less than 20 minutes and all information provided will remain anonymous and be treated as strictly confidential. Your participation is valuable to our research and is highly appreciated.

1. Please respond to all questions.
2. Give your honest views without consulting others.

Submission of this completed survey implies your consent to participate.

1. How long you have been on board a ship?

For a Visit		Up to a week		Up to a month	

More or less? Please specify

2. Did you ever learn maritime Ergonomics, Human Factors or Human Centred Design approach during your engineering education (undergraduate or school)?

Yes		No	

(If 'Yes', please go the question number 3, if 'No', please go the question number 6)

3. How do you define Human Factors?

4. How do you define Ergonomics?

5. How do you explain Human Centred Design approach?

6. Please circle the numbers to indicate whether you:

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
Human errors contribute to most marine casualties and accidents	1	2	3	4	5	6
The underlying causes for the maritime accidents, many of them are linked with Human Factor issues	1	2	3	4	5	6

7. Please list basic Human Factor issues on board a ship that you know need to be addressed adequately?

8. Please rank following in the order of importance for minimising or eliminating most of the onboard accidents linked with Human Factor issues.

Shield against the problem	
Warn the problem	
Design the problem out	
Train the operator/seafarer to avoid the problem	

9. Please explain your viewpoint/understanding about naval architects' responsibility to design the ship that is user-friendly?

10. Please explain your opinion on the paramount importance of proper understanding of Human Factors and Human Centred Design by a Naval Architect to design usable ships?

11. Please list any maritime design guidelines support designers to incorporate Human Factor requirements into the design?

Appendix C

Record sheets – HF-related onboard activities

Instructions

All information provided in this record sheet will remain anonymous and be treated as confidential. Your participation is valuable to our research and is highly appreciated.

1. Please respond to all questions.
2. Give your honest views without consulting others.
3. Fill in answers on separate paper

Please note that the activities will be recorded and converted to still images to use in publications within the project period.

Submission of this completed Record Sheet implies your consent to participate.

1. Activity you were involved in (number or name of activity).

2. What are the design failures which may cause discomfort or disturb personal access routes of the seafarers that you experienced during your activity?

3. What are your suggestions to improve the design failures you identified during your activity?

4. Based on today's experience what is your opinion about applying HCD discipline in ship design? Please explain your answer.

5. What are the benefits you recognise that seafarers may receive by applying HCD to ship design?

6. Do you like to experience more of HCD?

7. What should we do better, what should we do next?

Appendix D

Semi-structured face-to-face interview questions

1. Explain your understanding about the importance of maritime HF and HCD within ship design process?

2. Explain HCD approach to ship design?

3. How did you practice HCD during your design project?

   Explain your experience (difficulties you faced, challenges, suggestions for those challenges if any).

4. How did you find this HCD scaffolding program? (Onboard activities, short lecture sessions on Fridays, workshops, and guest lectures)

5. Are you happy with the HF and HCD pamphlets, reading materials, videos, and other supporting materials we provided?

6. What improvements we should make in scaffolding program and materials?

7. Tell us your thoughts/views on the framework we followed during this program (the connection between facilitators and you and the connection between you and your members).

8. How did you motivate your team in HCD application? Explain your experience.

Appendix E

Online questionnaire

1. Explain Human Factors (HF) and Human Centred Design (HCD)?

2. Explain your understanding about importance of HF and HCD within ship design process?

3. Tell us what you know about the application of HCD approach to ship design/offshore design/system design?

4. Tell us how your peer leader/HCD champion motivated, facilitated, and guided you to learn HF and HCD and apply newly acquired knowledge into design project?

5. How did you practice HCD during your design project?
   Explain your experience (difficulties you faced, challenges, suggestions for those challenges if any)

6. How did you find group HCD activities? Explain your experience
   - Onboard activities
   - ‘designers meet end-users’ workshops
   - Guest lectures.

7. Are you happy with the HF and HCD pamphlets, reading materials, videos, and other supporting materials we provided?

8. What improvements we should make in group workshops and HCD guidance materials? Please provide your feedback and suggestions

9. Tell us your thoughts/opinions on the framework we followed during this program (the connection between facilitators and your team HCD champion and the connection between you and HCD champion).

Appendix F:

HF and HCD introductory lecture – Action cycles 1 and 2

Action cycle 1	
Topic	**Description**
1. Human error vs less user-friendly designs	Discussed some of the resent maritime accidents in conjunction with the following topics. • Why human error remains the dominant factor of most of the maritime accidents? • How human error can be connected to user-friendly designs? • How can we minimise the potential to human error?
2. Elimination of HF problems.	Explained 'design the problem out' as the primary approach to the elimination of HF engineering problems. If the problem cannot be designed out, then the following approaches were suggested. • Shield against the problem • Warn of the problem • Train the operator. Explained the necessity of HF knowledge and skills of designers in order to design user-friendly designs.
3. HCD and usability.	Explained the HCD approach and usability aspects of maritime designs within the following topics. • General explanation to the interdependence of HCD activities • Benefits of HCD approach in brief • Usability and its definition: The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.
4. Good and bad design examples	• Explained few failure stories of ship designs, which were affected by the neglected end-user requirements. • Explained how those designs lead to modifications costing significant losses to the owner in terms of time and money. • Explained the real situation inside the design office with work pressure and tight schedules and how the designers could have taken HCD approach if they are aware and knowledgeable. • Used the same poor design examples to convince the students that 'common sense is not common for all'. • Explained a success story of a usable ship design.
5. Debrief of the visit to AMC training vessel Bluefin.	• Explained the details of activities done onboard. • Showed videos took during the onboard activities. • Explained the outcomes of those activities including, what we learned, design issues found onboard and how it could have minimised during the concept design stage.
6. Class exercise.	Showed a few pictures of accidents and asked the students to give their opinions on how to eliminate them.

Action cycle 1	
Topic	**Description**
7. How to become a HCD champion.	Explained the HCD champion concept and how to take the leadership to integrate HCD concept within the final year designs.

Sources used by the researcher:

- Rothblum, A. M. (2000). Human Error and Marine Safety. United States: United States Coast Guard Research and Development Centre.
- Squire, D. (2014). Human Element Competencies for the Maritime Industry. Paper presented at the Human Factors in Ship Design and Operation, Royal Institute of Naval Architects, London, UK, 26-27 February.
- Alert! Issue No.1 centrespread – Exploring the human element.
- Maguire, M. (2001). Methods to Support Human-Centred Design. International journal of human computer studies, 55(4), 587-634.
- ISO 9241-210. (2010). Ergonomics of human-system interaction - part 210: Human-centred design for interactive systems (ISO 9241-210). Geneva: International Organisation for Standardisation.
- The Nautical Institute. (2015). Improving Ship Operational Design (2 ed.). London, UK: The Nautical Institute.
- Abeysiriwardhane, A., Lützhöft, M., & Enshaei, H. (2014). Human Factors for Ship Design; Exploring the Bottom Rung. Transactions of the Royal Institution of Naval Architects Part C1: International Journal of Marine Design, 156(1), 153-159.

Modifications to the lecture during Action cycle 2
• During delivery of the second topic, i.e. elimination of HF problems, explained more about why the ‘design the problem out’ option comes always first priority to minimise HF issues onboard rather letting the users to adapt to the design. • During delivery of the fourth topic, i.e. good and bad design examples, more examples from user friendly designs were included to show the students the initiatives taken by the industry and to motivate them to use HCD concepts in their final year designs.

Appendix G:

Invitation flyer – Action cycles 1 and 2

Appendix H:

HCD knowledge dissemination activities

1. Session 1

<table>
<tr><th colspan="2">Action cycle 1</th></tr>
<tr><td>Instructional scaffolding.</td><td>Delivered a short lecture on following topics.
• Introduction to HF – Definition of HF, Goals of HF, HF in maritime domain, Maritime accidents and HF, Recognition of Human Element by The international Maritime Organisation (IMO) Resolution A.947(23).

• Introduction to Ergonomics – Definition of Ergonomics, Take account of ergonomic criteria in conceptual design stage: design for the smallest, largest and average users and, design for a range of users.

• Introduction to HCD – Definition of HCD, General explanation to interdependence of HCD activities.

Then a discussion session was conducted named 'Santa Claus Exercise', where Santa was taken as an example and requested students to think and speak out about various designs for Santa, if Santa is the user.</td></tr>
<tr><td>Scaffolding materials distributed to students.</td><td>• HCD Pamphlet 1 – covered topics delivered during the session.
• Alert! Video 1– The Human Element (http://www.he-alert.org/en/videos.cfm)
• Alert! Video 2– Human Factors (http://www.he-alert.org/en/videos.cfm)
• Alert! Video 3– Ergonomics (http://www.he-alert.org/en/videos.cfm)
• Alert! Issue No. 2 page 2 – Some thoughts from the sharp end.
• Alert! Issue No. 3 page 3 – The case for a decent design.
• Alert! Issue No. 25 page 1 – It's all about team work.
• Alert! Issue No.1 centrespread – Exploring the human element.
• Alert! Issue No.3 centrespread – Establish ergonomic criteria for the design.
• Research article - designing usable ships (http://www.he-alert.org/filemanager/root/site_assets/standalone_pdfs_0355-/HE00360.pdf)</td></tr>
<tr><td colspan="2">Sources used by the researcher:
• ISO 9241-210. (2010). Ergonomics of human-system interaction - part 210: Human-centred design for interactive systems (ISO 9241-210). Geneva: International Organisation for Standardisation.
• Alert! (2003). The international maritime human element bulletin. from The Nautical Institute www.he-alert.org
• Lloyd's Register. (2008). The Human Element - An Introduction. London, UK: Lloyd's Register Group.
• Maguire, M. (2001). Methods to Support Human-Centred Design. International journal of human computer studies, 55(4), 587-634.
• Sherwood Jones, B. (2005). Twenty Years on the Wrong Heading Dead Ahead. Paper presented at the Human Factors in Ship Design, Safety and Operation, Royal Institute of Naval Architects, London, UK, 23-24 February.
• Earthy, J., & Sherwood Jones, B. (2010). Best Practice for Addressing Human Element Issues in the Shipping Industry. Paper presented at the International Conference on Human Performance at Sea (HPAS), Glasgow, UK, 16-18 June.</td></tr>
</table>

Action cycle 2
Following modifications were done during the second action cycle.

Modifications to instructional scaffolding

- After the ‘Santa Claus exercise’, HF failure and success stories were discussed with the students

Failure story

In order to manually open the air starting valve of the main engine onboard a merchant ship, operator had to stand on the electric motor of the turning gear.

Image copyright: Include reference

Success story

Example of good access to valves and service components.

Image copyright: Include reference

Additional scaffolding materials distributed to students

- Andersson, M., and Lützhöft, M. (2007). Engine control rooms-human factors. Paper presented at the Human Factors in Ship Design,Safety & Operation, London,UK.

Additional sources used by the researcher

- Andersson, M., and Lützhöft, M. (2007). Engine control rooms-human factors. Paper presented at the Human Factors in Ship Design,Safety & Operation, London,UK.
- Dobbins, T., Rowley, I., and Campbell, L. (Eds.). (2008). High speed craft human factors engineering design guide: Human Sciences & Engineering Ltd.

2. Session 2

<table>
<tr><th colspan="2">Action cycle 1</th></tr>
<tr><td>Instructional scaffolding.</td><td>Delivered a short lecture on introduction to the first step of the HCD cycle – Plan the Human Centred Design process, and explained designers’ responsibilities during the HCD planning process. The following are the key areas discussed:

ISO 9241-210 - HCD cycle.
Why the designers must plan the process carefully in order to design user friendly design?
How to include ‘usability’ in to the project objectives?
How to ensure a HCD approach within the design team? Explained the following key points to assure such

Bring together various stakeholders to discuss and agree to keep usability as one of the key objectives within the design process.
Explain benefits of the HCD to the stakeholders and design team members.

Planning the HCD – explained the following key steps in order to support the planning of HCD within their design projects

Plan context of use analysis – use following questions
Why is this ship/system needed?
What are the overall objectives of your project?
What are the key functions going to be performed?
Who are the intended users?
Where will this design be used /operated?
Good and Bad lessons learned from previous designs?
Plan user involvement and evaluation
Plan design evaluation methods.

</td></tr>
<tr><td>Scaffolding materials distributed to students.</td><td>
HCD Pamphlet 2 – covered all topics delivered during the session.
Alert! Issue No. 24 – Naval Architect and Designers skills.
Alert! Video 7– Design and Usability. (http://www.he-alert.org/en/videos.cfm)
The Human-Centred Approach - A Best Practice Guide for Ship Designers, A Lloyd’s Register guide. (http://www.webstore.lr.org/products/716-the-human-centred-approach-a-best-practice-guide-for-ship-designers.aspx)
Research article – Earthy, J., & Sherwood Jones, B. (2010). Best Practice for Addressing Human Element Issues in the Shipping Industry.
The Human Element – an introduction, A Lloyd’s Register guide. (http://www.he-alert.org/filemanager/root/site_assets/standalone_article_pdfs_0605-/he00740.pdf)
Research article - McCartan, S., Harris, D., Verheijden, B., Lundh, M., Lützhöft, M., Boote, D., Hopman, J., Smulders, F., & Norby, K. (2014). European Boat Design Innovation Group; The Marine Design Manifesto.
</td></tr>
<tr><td colspan="2">Sources used by the researcher:

ISO 9241-210. (2010). Ergonomics of human-system interaction - part 210: Human-centred design for interactive systems (ISO 9241-210). Geneva: International Organisation for Standardisation.
Maguire, M. (2001). Methods to support human-centred design. International journal of human-computer studies, 55(4), 587-634.
Lloyd's Register. (2014). The human-centred approach- a best practice guide for ship designers: Lloyd's Register.
Alert! (2003). The international maritime human element bulletin. The Nautical Institute www.he-alert.org.
</td></tr>
</table>

Action cycle 2

The following modifications were done during the second action cycle.

<u>Modifications to instructional scaffolding</u>

- After the short lecture HF failure and success stories were discussed in the class to signify the value of HCD process.

Failure story

Offshore crane operator assistant (Dogman) climbing on top of a stack of stored pipes in order to guide a load.

Image copyright: Include reference

Success story

Walk to Work (W2W) offshore wind farm support vessel design by Damen Shipyard was taken as an example to explain how to carefully plan HCD process by a designer.

<u>Additional scaffolding materials distributed to students</u>

- Walk to Work (W2W) ship brochure. (http://www.wavec.org/content/files/04_Damen_Wavec_25112013.pdf)
- W2W ship - Damen ship video. (https://www.youtube.com/watch?v=GtU_LdA9iZo)
- NOPSEMA (Ed.). (2015). Human factors in engineering and design: National Offshore Petroleum Safety and Environmental Management Authority.

<u>Additional sources used by the researcher</u>

- NOPSEMA (Ed.). (2015). Human factors in engineering and design: National Offshore Petroleum Safety and Environmental Management Authority.
- W2W Animation. (https://www.youtube.com/watch?v=GtU_LdA9iZo)
- W2W brochure. (http://www.wavec.org/content/files/04_Damen_Wavec_25112013.pdf)

3. Session 3

<table>
<tr><th colspan="2">Action cycle 1</th></tr>
<tr><td>Instructional scaffolding.</td><td>Delivered a short lecture on introduction to the second step of the HCD cycle – Understand and Specify the Context of Use (CoU). The following are the key areas discussed:

Understand CoU.

User characteristics – user types (primary and secondary users), physical characteristics (anthropometry)
Tasks – primary tasks, frequency, importance, criticality
Hazards/ Risks – slip, trip and fall hazards
Operating environment – temperature, humidity, noise, light, workplace layout, spaces.

How do we analyse CoU:

Who (are you designing for), Who will be using the design?
What (do they do at work), What tasks or activities will the design are used to perform or support?, What will be the operating environment?
When (time of day, time of year),
Where (indoors, outdoors, noise, light, space).
Will the design be used in one situation or several?
What else will the design is used with, i.e. associated equipment or activities of the design?.

Then a discussion session was conducted to talk about the outline of their design projects and to assist them to initiate the CoU analysis of the design.</td></tr>
<tr><td>Scaffolding materials distributed to students.</td><td>

HCD Pamphlet 3 - covered all topics delivered during the session.
Alert! Issue No. 7 Know thy users - for they are not you! (http://www.he-alert.org/index.cfm/bulletin/Design-and-usability)
Alert! Issue No. 17 centrespread - Mitigating slip, trip and fall hazards. (http://www.he-alert.org/index.cfm/bulletin/Accidents)
Human-centred development - Putting the principles into practice, A Lloyd’s Register Guide (page 5-6). http://www.maritimes.gr/ennews/uploads/LR/Human-centred%20development_Version%201.1_102016.pdf)
Anthropometry data tables - EBook link to the book ‘Bodyspace’ by Pheasant Stephen - Library of University of Tasmania.
</td></tr>
<tr><td colspan="2">Sources used by the researcher:

ISO 9241-210. (2010). Ergonomics of human-system interaction - part 210: Human-centred design for interactive systems (ISO 9241-210). Geneva: International Organisation for Standardisation.
Lloyd's Register. (2008). Human-centred development - putting the principles into practice: Lloyd's Register.
Alert! (2003). The international maritime human element bulletin. from The Nautical Institute www.he-alert.org
Pheasant, S., and Haslegrave, C.M. (2016). Bodyspace: Anthropometry, ergonomics and the design of work: CRC Press.
</td></tr>
</table>

Action cycle 2

The following modifications were done during the second action cycle.

<u>Modifications to instructional scaffolding</u>

- After the short lecture the following two pictures of a ‘mooring task’ onboard a ship was showed to the students and invited them to a discussion on people, tasks, risks/hazards, and the operational environment.


Image copyright: Include reference

<u>Additional scaffolding materials distributed to students</u>

- Alert! Video 9– Operations (http://www.he-alert.org/en/videos.cfm)
- Alert! Video 14– Communication (http://www.he-alert.org/en/videos.cfm)
- Anthropometry data tables from Royal Australian Navy.

<u>Additional sources used by the researcher</u>

- Mooring – Do it Safely. (Danish Maritime Authority and the Danish Shipowners’ Association)
- Important Points to Remember During Mooring Operation on Ships. http://www.marineinsight.com/marine-navigation/10-important-points-remember-mooring-operation/

4. Session 4 – part A

Action cycle 1	
Instructional scaffolding.	Continued teaching on the topic 'understand and Specify the Context of Use' (CoU) - how do you learn CoU of your design? The following key methods were discussed. • Meet experienced seafarers and learn CoU from them. • Spend time onboard, study different work scenarios, people and material movement through the ship, the parallel flow of tasks for different crewmembers and the integrated use of tools and equipment. • Participate during the onboard operations. • Learn from success and failure stories, watch movie clips, and read blogs.
Scaffolding materials distributed to students.	• HCD Pamphlet 4 - covered all topics delivered during the session. • Useful movie clips to stimulate the CoU knowledge of the students. (see few examples below) https://www.youtube.com/watch?v=fqbOhfFJIBU,https://www.youtube.com/watch?v=aIHstC0nlv8 https://www.youtube.com/watch?v=4ueqDeDtAcU https://www.youtube.com/watch?v=zK51hlF4Izw https://www.youtube.com/watch?v=ua-ppReV684 https://www.youtube.com/watch?v=8yOWnElS5Ek https://www.youtube.com/watch?v=bi6EDaUpPGs&index=12&list=PLInAOQFAm4LNeP74K80BAeZShqAR0kDgu
Sources used by the researcher: • Alert! (2003). The international maritime human element bulletin. from The Nautical Institute www.he-alert.org • Maguire, M. (2001). Methods to support human-centred design. International journal of human-computer studies, 55(4), 587-634. • The Nautical Institute. (1998). Improving ship operational design (1 ed.). England: O'Sullivan Printing Corporation.	

Action cycle 2
The following modifications were done during the second action cycle. Modifications to instructional scaffolding • After the short lecture, example of the design of W2W ship was taken again to explain how those designers analysed CoU within their design. Additional scaffolding materials distributed to students • A mind map was made using Mindmeister® online software and more videos were added to it to improve the students CoU knowledge. Additional sources used by the researcher • Monchy, M.M., and Smit, B.D. (2015). Landlubber to seaman-an industrial design approach in the process of getting highly specialised onshore personnel to work offshore. Paper presented at the International Conference on Marine Design 2015, London, UK.

Session 4 – part B

<table>
<tr><th colspan="2">Action cycle 1</th></tr>
<tr><td>Instructional scaffolding.</td><td>Conducted a low-fidelity (lo-fi) prototype workshop.

Champions and their team members were asked to build low fidelity prototypes of selected work contexts on ships (see below), and to prepare mobile phone videos of a scenario.
<u>No</u> <u>Work context on a ship</u>
01 Ship Bridge when arriving in a port
02 Ship Engine room (ER) /Engine control room (ECR) before departure
03 Ship mooring station preparing for arrival
04 Ship mess/galley preparing for the Captains Birthday
05 Ship life boat station is doing lifeboat drill

Following instructions were given to them regarding their task:
• Assume one of your overseas based design project clients wants to see an overview of a work situation of one area of your design
• You must show them that the relevant personnel fit in the area and the tasks can be performed effectively, efficiently and satisfactorily
• You have to make a lo-fi prototype of this work area for the client to oversee
• Make a 3 minute demonstration video showing the use of your design
• Present your demonstration to an expert team available and obtain their feedback.

Each team were provided with lo-fi materials including but not limited to, cardboard boxes, corrugated sheets, wooden mannequins, scissors, glue, tapes, drawing pins, pens, pencils, rulers, data cables etc. A team of six end-user representatives were available as end-users, for consultation. Once all teams finished with their designs and videos, representatives from each team presented the videos to the end-user representatives and to the whole class. The end-user representatives then provided their feedback on each design to students. A questionnaire and reading materials were distributed at the end of the session. All champions and their team members were invited to attend this session.</td></tr>
<tr><td colspan="2">Sources used by the researcher:
• Alert! (2003). The international maritime human element bulletin. from The Nautical Institute www.he-alert.org
• The Nautical Institute. (1998). Improving ship operational design (1 ed.). England: O'Sullivan Printing Corporation.
• Lande, M. & Leifer, L., 'Prototyping to Learn: Characterizing Engineering Students' Prototyping Activities and Prototypes', International Conference on Engineering Design, ICED'09, USA, 2009.</td></tr>
</table>

<table>
<tr><th>Action cycle 2</th></tr>
<tr><td>Based on the lessons learned from the previous cycle, this workshop session did not conduct during the second cycle. However, the champions were introduced to the lo-fi prototyping concept and its importance during the scaffolding session 4A in order to let them decide on preparing prototypes of their designs.</td></tr>
</table>

5. Session 5

Action cycle 1	
Instructional scaffolding.	Four experienced seafarers delivered short (15-20 minutes) guest lectures on the following. • The seafarers' job profile (Ex: Captains and Chief engineers explained their jobs) • The difficulties they face during their life onboard due to design failures • Their feedback and suggestions for designers.

<table>
<tr><th colspan="2">Action cycle 2</th></tr>
<tr><td colspan="2">Session 5 was completely changed as it was planned to allocate more time to teach and discuss the topic 'understand and specify the CoU'. In addition a guest lecture was arranged to all the students. Therefore, session 5 was modified as the following two sessions: session 5A – understand and specify the CoU, and session 5B – guest lecture.</td></tr>
<tr><td colspan="2">Session 5A</td></tr>
<tr><td>Instructional scaffolding.</td><td>
Delivered a short lecture on understand and Specify the Context of Use (CoU) - how do you analyse CoU? The following are the key methods that discussed.

- Analyse scenarios of use:
Description - Scenarios give detailed realistic examples of how users may carry out their tasks. Scenarios encourage designers to consider the characteristics of the intended users, their tasks and their environment, and enable usability issues to be explored at an early stage in the design process.
Then following example scenarios were introduced to students to analyse.
    - Can you evacuate a person on a stretcher from all spaces?
    - How do spares and provisions transport from dockside to the deck and then to the galley, to storage? How are other supplies taken on and off the ship?
    - Is there room for teamwork on the bridge?
    - Does the engine control room provide overview, as well as a planning and resting space and an administrative workplace?
- Use virtual tours of ships to find out different logistical and personal access routes and details of working spaces. The online virtual tour of RV investigator research vessel done by Commonwealth Scientific and Industrial Research Organisation (CSIRO) was showed to the students.

Then one success story and two HF failure stories were introduced and discussed with students. (see below)

<u>Success story</u>

Adequate comfort in accommodation

Image copyright: Include reference

Continue on next page.
</td></tr>
</table>

<table>
<tr><td></td><td>

<u>Failure stories</u>

A narrow and cramped ECR

Image copyright: Include reference

Cramped accommodation

Image copyright: Author

</td></tr>
<tr><td>Scaffolding materials distributed to students.</td><td>

- HCD Pamphlet 5 - covered all topics delivered during the session.
- RV Investigator research vessel virtual tour. (http://www.csiro.au/RV-Investigator-virtual- tour/rv_investigator.html?html5=prefer)
- Cyclades E-Learning. (http://elearning.cyclades-project.eu/)

</td></tr>
<tr><td colspan="2">

Sources used by the researcher:

- RV Investigator research vessel virtual tour. http://www.csiro.au/RV-Investigator-virtual-tour/rv_investigator.html?html5=prefer
- Maguire, M. (2001). Methods to support human-centred design. International journal of human-computer studies, 55(4), 587-634.
- Cyclades E-Learning. http://elearning.cyclades-project.eu/

</td></tr>
<tr><td colspan="2">Session 5B</td></tr>
<tr><td>Instructional scaffolding.</td><td>

Experienced Captain of a ship delivered one hour guest lecture.
Lecture was consist of:

- His current job profile as a Captain of a FPSO ship and critical tasks
- His previous job profiles during the journey to Captain
- One major operational scenario of FPSO – Ship to ship loading operation
- Difficulties faced during his life onboard due to design failures
- His feedback and suggestions for designers based on his experience.

Photo taken during the guest lecture conducted by an experienced seafarer – Master mariner of a Floating Production Storage Offloading ship (picture used with informed consent).

</td></tr>
</table>

6. Session 6

<table>
<tr><th colspan="2">Action cycle 1</th></tr>
<tr><td>Instructional scaffolding.</td><td>Delivered a short lecture on introduction to the third step of the HCD cycle – Specify the user requirements.

The following are the broad topics that explained to the students to understand how to specify the user requirements:
• Introduction to user requirements: Habitability, Maintainability, Workability, Controllability, Manoeuvrability, Survivability
• What does Habitability includes?
• What does Maintainability includes?
• What does Workability includes?
• What does Controllability includes?
• What does Manoeuvrability includes?
• What does Survivability includes?.

Classroom discussion was then conducted to talk about the user requirements within their design projects.</td></tr>
<tr><td>Scaffolding materials distributed to students.</td><td>• HCD Pamphlet 6 - covered all topics delivered during the session.
• Alert! Issue No. 11 – The Human Element jigsaw. (http://www.he-alert.org/index.cfm/bulletin/Integration)
• Alert! Issue No. 34 – Habitability. (http://www.he-alert.org/index.cfm/bulletin/habitability)
• Alert! Issue No. 36 –accessibility & manoeuvrability. (http://www.he-alert.org/index.cfm/bulletin/operability-accessibility-manoeuvrability)
• Alert! Issue No. 37 – Survivability. (http://www.he-alert.org/index.cfm/bulletin/survivability)
• Alert! Issue No. 40 – Addressing the human element considerations. (http://www.he-alert.org/index.cfm/bulletin/survivability)
• Research articles – specify user requirements in luxury yacht designs (see below)
McCartan, S., Moody, L., & McDonagh, D. (2011). An Emotional Design Approach to Luxury in the Design of a 40ft Sailing Yacht.
McCartan, S., Moody, L., & McDonagh, D. (2011). An Emotional Design Approach to Luxury in Superyacht Interior Design.
McCartan, S., Roy, J., & Starkel, R. (2011). Design-Driven Innovation: A High Speed Coastal Cruiser for the Chinese Luxury Market.
McCartan, S., Verheijden, R., Roy, J., & Nuvolari-Duodo, C. (2013). Design-Driven Innovation of a High Speed Art Deco Superyacht Coastal Cruiser for the Chinese Market.
Barrett, A., Crea, N., & McCartan, S. (2015). Emotional Design and the exterior styling development of a WFSV.</td></tr>
<tr><td colspan="2">Sources used by the researcher:
• Lloyd's Register. (2008). The human element - an introduction: Lloyd's Register Group.
• Alert! (2003). The international maritime human element bulletin. from The Nautical Institute www.he-alert.org
• EBDIG. (2014). Lifelong Learning Programme. Retrieved 29 June, 2015, from http://ebdig.eu/</td></tr>
</table>

<table>
<tr><th colspan="2">Action cycle 2</th></tr>
<tr><td colspan="2">The scaffolding session 6 of action cycle 2 was modified to have the following two sessions:
• Session 6A – Short lecture on the topic ‘specify the user requirements’
• Session 6B – guest lecture.
During session 6A, one HF failure story and success story was introduced and discussed with students, in addition to the lessons delivered in scaffolding session 6 of action cycle 2.</td></tr>
<tr><td colspan="2">Session 6A</td></tr>
<tr><td colspan="2"><u>Modifications to instructional scaffolding</u>
After the class discussion, HF failure story and success stories were introduced and discussed with the students.

Failure story
Bad ladder design, which has access to the weather deck and is a frequent uses for material handling.

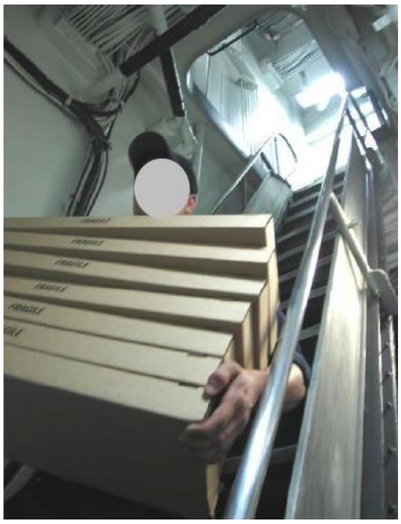



Image copyright: Cyclades
Success story
W2W offshore wind farm support vessel design by Damen Shipyard was taken again to explain how those designers specified user requirements during the design process of that vessel.

<u>Additional sources used by the researcher</u>
• Cyclades E-Learning. (http://elearning.cyclades-project.eu/)
• Monchy, M.M., and Smit, B.D. (2015). Landlubber to seaman-an industrial design approach in the process of getting highly specialised onshore personnel to work offshore. Paper presented at the International Conference on Marine Design 2015, London,UK.</td></tr>
<tr><td colspan="2">Session 6B</td></tr>
<tr><td>Instructional scaffolding.</td><td>Experienced Chief Engineer and a Deck Cadet of a ship delivered one hour guest lecture. Lecture was consist of:
• Seafarers’ current job profile, their responsibilities and critical tasks.
• Difficulties they faced during their life onboard due to design failures.
• Feedback and suggestions for designers based on their experience.</td></tr>
</table>

7. Session 7

Action cycle 1

Instructional scaffolding.

Delivered a short lecture on introduction to the fourth step of the HCD cycle – Produce design solutions to meet user requirements. The following are the key points discussed:

- How do we produce design solutions?
    - Design all layouts, taking into consideration the user requirements
    - Use existing knowledge (HF standards, guidelines, examples of other systems) to produce design solution
      Examples: Guidance notes on the application of ergonomics to marine systems, ABS; Guide for crew habitability on ships, ABS; Maritime Labour Convention 2006 (Accommodation, recreational facilities, food and catering)
    - Trade-off usability against other design criteria
    - Alter the design solutions in response to user evaluation and feedback
    - Communicate the design solutions to those responsible for their implementation
    - Iterate HCD process until design objectives are met.

Then the discussion session was conducted to talk about success stories of HCD (see below).

Success story 1
Altering personal access routes within demanding working spaces taking user into consideration

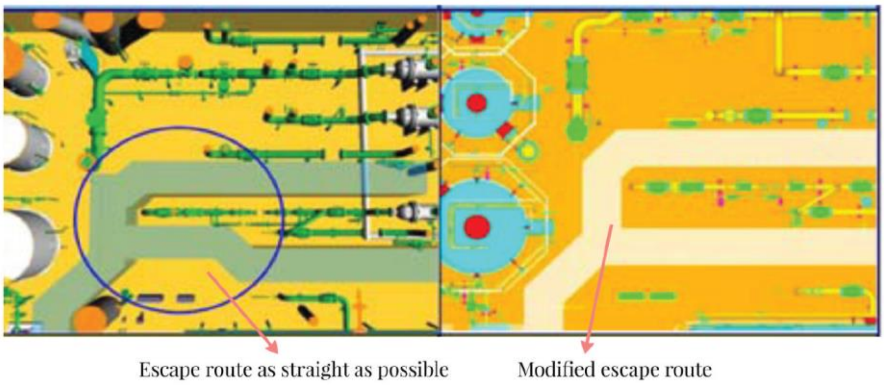


Image copyright: K.P. McSweeney, J Pray and B.N. Craig

Success story 2
Analysis of working scenarios of users to produce design solutions
Example: Offshore Wind Farm Support Vessel design by Damen Shipyard
Scenario 1 – Home to work
Scenario 2 – A regular day offshore
Scenario 3 – A free day offshore (used below figures)

Continue on next page.

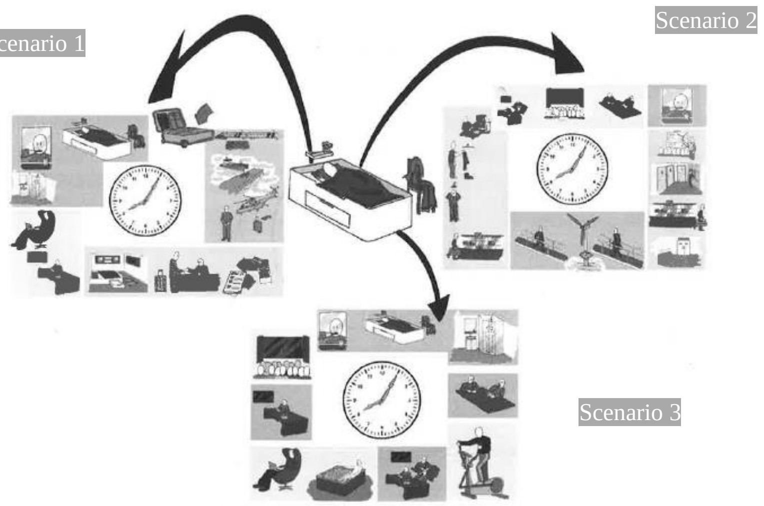


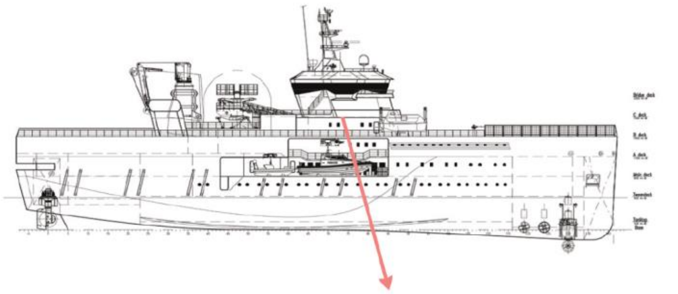
Figure 1a: The working and leisure life offshore

Image copyright: M. M. Monchy (Include reference)

Success story 3
Produce design solutions
Example: Offshore Wind Farm Support Vessel design by Damen Shipyard

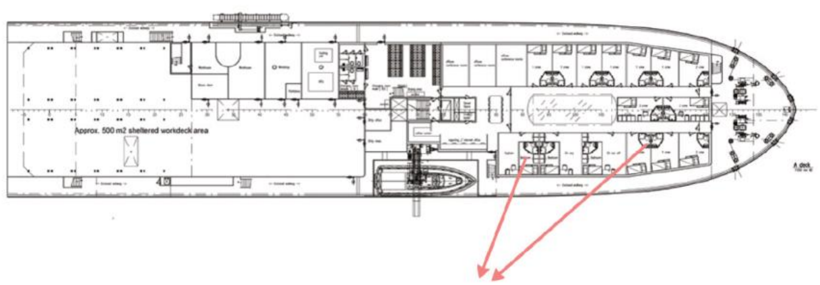
Seakeeping, stability, and controllability

Seasickness and motion induced limitations need to be considered in the general hull design and in the general arrangement



Accommodation areas are located amidships to minimise vertical accelerations (30 % below a conventional PSV)

Habitability requirements taken into consideration



Every single cabin has separate bathroom (comply with MLC 2006)

Image copyright: M. M. Monchy

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<table>
<tr>
<td></td>
<td>Success story 4
Lifeboat design by Royal National Lifeboat Institute

The RNLI Tamar Class Lifeboat engine throttles are operated via finger-tip control; also visible are the trackball and its control buttons to the right of the throttle controls, SIMS display screen, radio microphone and cup-holder. (see two figures below)
 
RNLI-FNC Suspension Seat HSC Man-Machine Interface design solutions
Image copyright: RNLI

Coxswain using arm-rest mounted throttle (right hand) and tiller (left hand) controls on the RNLI Tamar Class Lifeboat

Image copyright: RNLI</td>
</tr>
<tr>
<td>Scaffolding materials distributed to students.</td>
<td>
HCD Pamphlet 7 - covered all topics delivered during the session.
W2W ship brochure. (http://products.damen.com/en/ranges/walk-to-work-vessel/w2w-9020)
W2W ship video (https://www.youtube.com/watch?v=GtU_LdA9iZo)
Research article - Monchy, M. M., & Smit, B. D. (2015). Landlubber to Seaman-An Industrial Design Approach in the Process of Getting Highly Specialised Onshore Personnel to Work Offshore.
Tamar class lifeboat. (https://www.youtube.com/watch?v=ehTyqCQ5mI0)
Research article - Nurser, J., & Chaplin, N. (2004). Development of Integrated Electronic System and Human-Machine Interface in a New Class of Lifeboat.
High speed craft human factors engineering design guide by Dobbins, T., Rowley, I., and Campbell, L.
Electronic copies of HF guidance documents discussed during the session.
</td>
</tr>
</table>

Sources used by the researcher: • Maguire, M. (2001). Methods to support human-centred design. International journal of human-computer studies, 55(4), 587-634. • Monchy, M.M., and Smit, B.D. (2015). Landlubber to seaman-an industrial design approach in the process of getting highly specialised onshore personnel to work offshore. Paper presented at the International Conference on Marine Design 2015, London, UK. • Royal National Lifeboat Institution (RNLI). (2016). The RNLI is the charity that saves lives at sea. Retrieved 29/06, 2016, from https://rnli.org/what-we-do/lifeboats-and-stations/our-lifeboat-fleet/tamar-class-lifeboat • Nurser, J., & Chaplin, N. (2004). Development of Integrated Electronic System and Human-Machine Interface in a New Class of Lifeboat. Paper presented at the SURV 6: Surveillance, Pilot and Rescue Craft, London, UK, 17-18 March.

Action cycle 2
Similar session was conducted during the second action cycle. However, when discussing success stories of HCD, full story of offshore wind farm support vessel design by Damen Shipyard was not discussed in detailed, since it was already explained step by step during the previous sessions of the second action cycle. Instead, how the Damen designers produced design solutions to satisfy the users of their vessel was discussed during this session.

8. Session 8

Action cycle 1	
Instructional scaffolding.	Delivered a short lecture on introduction to the fifth step of the HCD cycle – Evaluate the designs against requirements. The following key methods were discussed: • End-users' or representatives' review or walkthrough • Evaluate the design using HF evaluation software. • Use existing knowledge guidelines, criterions or check lists to evaluate design solution.
Scaffolding materials distributed to students.	• HCD Pamphlet 8 - covered all topics delivered during the session.
Sources used by the researcher: • Maguire, M. (2001). Methods to support human-centred design. International journal of human-computer studies, 55(4), 587-634. • Lloyd's Register. (2014). The human-centred approach- a best practice guide for ship designers: Lloyd's Register. • McCartan, S., Harris, D., Verheijden, B., Lundh, M., Lützhöft, M., Boote, D., Hopman, J., Smulders, F., & Norby, K. (2014). European Boat Design Innovation Group; The Marine Design Manifesto. Paper presented at the International Conference on Marine Design 2014, Royal Institute of Naval Architects, Coventry, UK, 3-4 September.	

<table>
<tr><th colspan="2">Action cycle 2</th></tr>
<tr><td colspan="2">During this session in action cycle 2, a short lecture was delivered to cover HF guidelines and their usage to produce design solutions.</td></tr>
<tr><td>Instructional scaffolding.</td><td>
Habitability guidelines.

Habitability guidance documents from Classification society American Bureau of Shipping (ABS)
Maritime Labour Convention 2006 (MLC 2006)

Ergonomic navigation bridge design guidelines.

Application of ergonomics to marine system design (ABS)
Ergonomic design of navigation bridge (ABS)
Bridge design (IACS Rec.95)
Ergonomic criteria for bridge equipment and layout (IMO/MSC/Circ.982).

Guidance on fatigue mitigation and management – Module 7, Shipboard Fatigue and Naval Architect.
Engine room layout design and arrangement (IMO/MSC/Circ.834).
Guidelines on the layout and ergonomic design of safety centres of passenger ships (IMO/NAV 55/12).
</td></tr>
<tr><td>Scaffolding materials distributed to students.</td><td>
HCD Pamphlet 8 - covered all HF guidelines.
Electronic copies of HF guidance documents.
</td></tr>
<tr><td colspan="2">Sources used by the researcher:

Maritime Labour Convention. (2006). MLC 2006 (Accommodation, recreational facilities, food and catering). International Labour Organisation.
American Bureau of Shipping. (2014). Guidance notes on the application of ergonomics to marine systems. Houston, TX, USA: ABS.
American Bureau of Shipping. (2013). Guide for crew habitability on ships. Houston, TX, USA: ABS.
American Bureau of Shipping. (2003). Guidance notes on ergonomic design of navigation bridges. Houston, TX, USA.
International Maritime Organization. (2001). Guidance on fatigue mitigation and management (MSC/Circ.1014). London, UK: IMO.
</td></tr>
</table>

9. Session 9

Action cycle 1	
Instructional scaffolding.	A 'Designers meet end-users' workshop was conducted for the HCD champions and their team members. Upon invitation, a team of seven seafarers were present as end-user representatives to walkthrough the students' designs to provide feedback and suggestions and to offer an opportunity for the students to interact with those who have experience onboard ships. Following instructions were given to all design project teams to facilitate end-user representatives: ▪ Explain your design project ▪ Show your 2D or 3D design drawings ▪ Explain expected operations and situations in which your design will be used ▪ Obtain expert's feedback to improve your design. Each design project team was given 60 minutes to communicate with their end-user representatives. Once all teams finished their design walkthrough with end-user representative, a feedback form was distributed to the students and they were given 10 minutes to complete them. Finally, students were requested to ask any relevant questions and, as a closing event the researcher had a closed debriefing session with end-user representatives to discuss and share individual comments and feedback on each design project. Notes taken by the end-user representatives during the walkthrough, and notes and observations recorded during the workshop by the researcher were discussed during the debriefing session with end-user representatives.

Action cycle 2
A short lecture covered the fifth step of the HCD activities was delivered. This session was similar to the scaffolding session eight of the previous action cycle (see Session 8 – Action cycle 1).

10. Session 10

Action cycle 1	
Instructional scaffolding.	A short lecture covering the introduction to HF evaluation software (HumanCAD®) was delivered. The following key points were discussed: • General layout of the software • How do we create mannequins • Pose and manipulate the mannequin • Import CAD files • Perform reach analysis • Perform vision analysis
Scaffolding materials distributed to students.	• HCD Pamphlet 10 - covered all topics delivered during the session.
Sources used by the researcher: • HumanCAD®Ergo tool and software instructions guide.	

Action cycle 2
This session was similar to the scaffolding session 10 of the previous action cycle (see Session 10 – Action cycle 1).

Appendix I:

Academic papers

These articles have been removed for copyright or proprietary reasons.

Abeysiriwardhane, A., Lützhöft, M., & Enshaei, H. (2014). Human Factors for Ship Design; Exploring the Bottom Rung. *Transactions of the Royal Institution of Naval Architects Part C1: International Journal of Marine Design, 156*(1), 153-159.

Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S., & Enshaei, H. (2015). Investigate and Stimulate Future Maritime Designers' Context of Use Knowledge: A Workshop Approach. *Transactions of the Royal Institution of Naval Architects Part C1: International Journal of Marine Design, 157*, 179-193.

Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S., & Enshaei, H. (2016). Human Centred Design Knowledge into Maritime Engineering Education; Theoretical Framework. *Australasian Journal of Engineering Education*, 21(2), 49-60, DOI:10.1080/22054952.2017.1287038

Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S., & Enshaei, H. (2017). Stimulating Human Centred Design Understanding and Awareness in Maritime Design Students: A Demonstration of an Action Research Approach. *Transactions of the Royal Institution of Naval Architects Part C1: International Journal of Marine Design*.

Incorporate good practice into ship design process; Future ship designers meet end users

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[a]*Australian Maritime College, an Institute of the University of Tasmania, Tasmania, Australia.*

A good ship design is one that takes account of socio-technical requirements and challenges; it has to fulfil the fundamental requirements of the safety, efficiency, and usability of the entire ship system by keeping Human Factors (HF) in mind. Human Centred Design (HCD) is an approach which designers can use to apply HF and user involvement into ship design. Thus the ship designers' expertise on HCD is of paramount importance for a good ship design.

This paper presents part of an ongoing research study to integrate HCD knowledge into the maritime design engineering education. A "Designers Meet Users" workshop was conducted with Bachelor of Engineering students at Australian Maritime College. A team of seven maritime field experts were present as end users to provide HF feedback to improve final year 'Design Projects' done by the students. Students facilitated a walkthrough of their designs to the field experts. Data collection included debriefing meeting with experts, student feedback, and researchers' observations.

Field expert team highlighted the possible design alterations within the general arrangement and other layout drawing to make the designs more user friendly than its original, indicating that the students had little or no HF knowledge or experience. Thus it is needed to integrate HF/HCD knowledge into maritime design engineering education system in a more targeted engineering-oriented fashion.

Keywords: human factors, human centred design, ship design, maritime designer, education

1. Introduction

'Everybody complains about the weather, but nobody does anything about it'. This quote is attributed to the American novelist Charles Dudley Warner (1829-1900), and is possibly expected to indicate that humans are habitually talking about things they certainly cannot do anything about. Arguably, Petersen (Petersen, Dittmann, & Lützhöft, 2011) understood something similar for the application of Human Factors (HF) in the maritime industry: '*Many talk about Maritime Human Factors, but few are doing anything about it*'. There are few records (Dobbins, Rowley, & Campbell, 2008; Petersen, 2012) of the industrial application of maritime HF in the systematic literature of the maritime domain. Nevertheless there are no accounts in the literature, of any systematic industrial application of maritime HF knowledge in ship design process. Moreover, in addition to a comprehensive literature on maritime HF, there are no regulation requirements for HF engineering in the maritime domain. However "*The past is already gone, the future is not yet here. There's only one moment for you to live, and that is the present moment (p 13)* (Kannings, 2014)":

thus now is the moment to consider how can we contribute to increasing the inclusion of HF consideration in ship design process – having an impact on the future.

The life of the seafarers is heavily dependent on the ship's design characteristics such as equipment accessibility, habitability, workability, maintainability, operability (Alert!, 2004; Hemmen, 2003; Lloyd's Register, 2008), usability, reliability, supportability, and acceptability (Alert!, 2010). Some design features affect the mental workload, some affect the crew's ability to sleep, and others affect the level of physical stress on the crew (Ellis, 2009; IMO, 2001). To ensure that a design is fit for the intended purpose and appropriate to the context in which it will be used, the designers and the design process should consider these aspects, an integral part being to consider the users' capabilities and limitations (Squire, 2014) through Human Centred Design (HCD) approach.

HCD is an approach which focuses on making systems usable by applying HF, ergonomics, and usability knowledge and techniques during design (ISO, 2010). According to the ISO 9241-210 standard, this approach enhances effectiveness and efficiency, improves human well-being and user satisfaction. In addition, it is noted that the HCD process is designed to maintain the consideration on user needs, through the direct and continuous involvement of end users, as a minimum for the duration of the development process or better, throughout the entire product life-cycle (Nielsen, 1993). Involving users in the design and development processes of new products, systems and workspaces has become increasingly important in order to improve the quality if the product, to increase the flexibility of their functions, and to prevent disturbances in system performance (Launis, 2006). End users can contribute important knowledge on workplace processes, tasks, equipment, and potential risks, and feedback on the design. Similarly the end user participation and feedback on maritime designs provides important information about how ships, their components and services are used, and can assist with informing design, improving usability aspects and enhancing operation. In more detail, user feedback informs designers of the good features to be continued and developed, the failures and weaknesses, potential risks and even ideas about how to improve them. A lack of user feedback and involvement during design stage increases the risk that the new design or innovation does not fit its user, the purpose and the context of use of actual practice.

The maritime design practice today does not show explicit consideration of the end user, and therefore does not apply HF, ergonomics and usability knowledge during design to their full extent (Calhoun & Stevens, 2003; Costa & Lützhöft, 2014; Petersen et al., 2011), if at all. In addition the design process does not appear to involve end users or obtaining end user feedback. There are few opportunities for maritime designers to communicate with end users, and no systematic feedback from users to designers. Designers and end users are by nature distanced by professional upbringing, knowledge and culture, and often also distanced both geographically and organisationally, due to the globalised nature of the maritime industry, all of which poses challenges to collaborative design. However it is of paramount importance for the designers to have early focus on end users, tasks and environment, to have an active involvement of users if possible and to incorporate end user derived feedback into the design. These points are what enables applying an HCD approach. Yet most of the maritime design engineers involved in the maritime design process seem to be unaware about HF, HCD and – noteworthy in the present context – the operational issues which ships' crew face during their sea time (Petersen, 2012; The Nautical Institute, 1998; Walker, 2011). This lack of knowledge can be traced back to the educational system which present maritime design engineering students are not fully aware of the HCD approach in ship design, maritime HF issues and HF guidelines (Abeysiriwardhane, Lutzhoft, & Enshaei, 2014; Abeysiriwardhane, Lutzhoft, Petersen et al., 2015). Examining their education system, it is clear that it is heavily biased towards the technological field and very few have been exposed to such topics as HF (Kuo & Houison-Craufurd, 2000; Walker, 2011). Furthermore there are rare opportunities for maritime design engineering students to communicate with those who work onboard the ships during their study period to stimulate their knowledge on operational issues and to establish a clear understanding of the situation in which the design will be used.

This paper presents part of an ongoing research study aiming at mitigating this knowledge gap, explicitly attempting to integrate HF/HCD knowledge into the maritime design engineering education. A "Designers Meet Users" workshop was conducted with 62 final year Bachelor of Engineering students (hereafter referred to as the 'students') at the Australian Maritime College (AMC) at the University of Tasmania in July 2015. A team of seven maritime field experts were present as end user representatives to provide HF feedback to improve final year 'Design Projects' done by the students. Students facilitated a walkthrough of their designs to the field experts. Data collection included debriefing meeting with experts, student feedback, and researchers' observations. The findings of this three-hour workshop are presented in this paper.

2. Methodology

The "Designers Meet Users" workshop was arranged as a part of the Bachelor of Engineering degree final year course unit 'Design Project', which has participation from the branches of Naval Architecture, Marine & Offshore Engineering, and Ocean Engineering. This unit has been developed at the AMC, and allows students to use and integrate knowledge acquired during their previous years of study, helping them to develop their ability to plan, research, conduct and manage a complex design project (Thomas, Harte, & Pointing, 2013; Thomas, Lawrence, & Furness, 2006). Students were invited to participate in the "Designers Meet Users" workshop by the Unit's lecturer seven days in advance and requested to be prepared with their designs to facilitate a walkthrough for the field experts in order to obtain their feedback and suggestions. Following instructions were given to all design project teams to facilitate field experts; 1) explain your design project, 2) show your 2D or 3D design drawings, 3) explain expected operations and situations in which your design will be used, 4) obtain expert's feedback to improve your design. Twelve design project teams were present at the workshop as listed in the Table 1.

The team of seven maritime field experts as listed in Table 2 were invited to walkthrough the students' designs to provide feedback and suggestions and to offer an opportunity for the students to interact with those who have experience onboard ships. The field expert team members were selected based on their seafaring and maritime experiences in regards to the students' final year design projects. The research team had reported to the expert team about the students' design projects, workshop procedure, and their role in the workshop about seven days in advance. Maritime field experts were assigned to different design projects as end user representatives (see Table 2).

A main moderator led the workshop that was undertaken in a computer workroom. Additionally, assistant moderators were present throughout the workshop to gather written informed consent from the participants, to take notes, and distribute feedback forms. In addition the assistant moderators provided general help and guidance to the workshop participants and expert team members. The feedback forms distributed to the students contained two questions; one scaled question and one open ended questions. The scaled question contained three verbal anchors, “Useful”, “Neutral” and “Irrelevant” to indicate the students’ satisfaction with the workshop. The open-ended question was included to obtain the students’ suggestions and feedback on the workshop activity. The results of the feedback are given in section 3.2.

Table 1. Design project teams.

Team	Project name
01	Design proposal for 70m Anchor Handling Tug Supply vessel
02	Design proposal for 60m Super Yacht
03	Design proposal for 52m Sailing Yacht
04	Design proposal for 45m Research and Training vessel
05	Design proposal for Disaster Relief barge
06	Preliminary design of a Submarine
07	Concept design of a Submarine Rescue Suite
08	Design proposal for Offshore Decommissioning vessel
09	Design proposal for Yacht Club Marina
10	Antarctic Gateway Project: AUV Launch and Recovery System design proposal
11	Redesign proposal for Davis Cat – AMC Research vessel
12	Design proposal for Naval Littoral Operational Support vessel

Table 2. Maritime field experts.

Team member	Assigned design project
Master Mariner 01	01,08
Master Mariner 02	12
Master Mariner 03	04,11
Seafarer (Submariner)	06,07
Seafarer/ Lecturer 01	02,03
Seafarer/ Lecturer 02	05
Naval Architect/ lecturer	09,10

2.1 Procedure of the workshop

A briefing was given to the students on how the workshop would be conducted and the maritime field experts were introduced and assigned to their design projects as end user representatives. The research team requested design groups to use their design tools such as 2D/3D design software or printed drawings to walkthrough the respective field experts in their designs. Each design project team was given 60 minutes to communicate with their field expert (see Figure 1). The research team also encouraged the students to communicate freely with any of the field experts after they completed the walkthrough. Once all teams finished their design walkthrough with field experts, a feedback form was distributed to the students and they were given 10 minutes to complete them. Finally, students were requested to ask any relevant questions and, as a closing event the research team had a closed debriefing session with field experts to discuss and share individual comments and feedback on each design project. Notes taken by the field experts during the walkthrough, and notes and observations recorded during the workshop were discussed in detail during the debriefing and individually with each field expert afterwards.

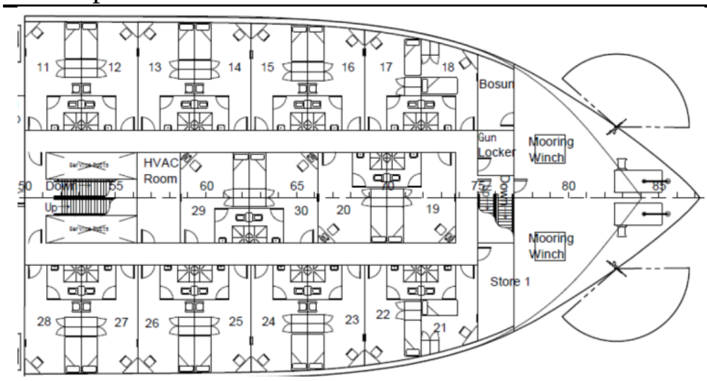
Figure 1. Field experts as end user representatives meet future maritime designers

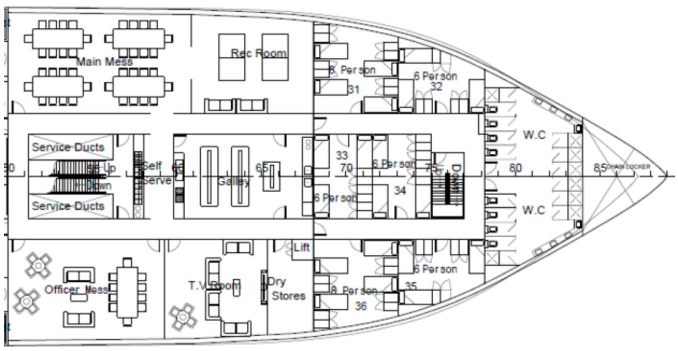
3. Results

3.1 Field experts debriefing session and researcher's observations

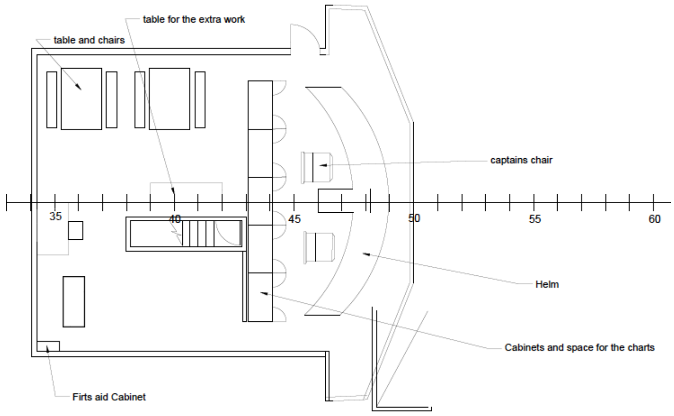
The field experts observed many instances in the concept design proposals, where students did not consider the user requirements of their designs such as habitability, maintainability, and workability. The experts identified a lack of consideration of the provision of adequate and comfortable accommodation, including location, space allocated, furnishings, and washing facilities. In addition, most of the teams did not consider the variations in the size, shape, and gender of the seafarer, and did not allow for the various environmental stressors such as noise, heat and vibration. Furthermore the consideration of access, designing operational maintenance routes, placing the machinery, and headroom considerations had to be improved in many design proposals. However, most of the designs could have been rearranged without deviating from the original design specification to make improvements in the crew habitability by rearranging the cabin locations, rearranging the furniture within cabins considering the directions, changing the staircase locations and angles, providing better headroom and providing natural light. Few examples taken from students' designs can be listed as below (seen Table 3).

Table 3. Few examples in changes highlighted within designs.

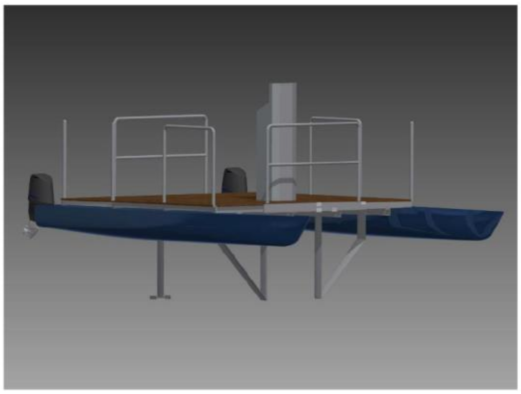
Example	Description
	Team 08 – Deck B Plan Team placed the bunks athwartships where roll motion is high and uncomfortable for the seafarers. Expert team suggested them to rearrange the layout to improve the crew habitability.



Team 08 – Deck A Plan
Main mess tables placed fore and aft direction where users feel uncomfortable while using them. Also a few 6-person cabins were placed within a busy area close to the recreation room and toilets. The layout could be rearranged to improve the crew habitability.



Team 04 – Bridge Plan
There was a row of tall cabinets with a few switchboards placed approximately 500mm behind the captain's chair making difficult for them to access them and obstructing rear visibility. This could have been rearranged to improve the visibility, equipment maintainability and accessibility requirements.



Team 11 – 3D Model
This small boat travels at 40knot speed with 6 people on-board it. The railing height is 600mm and also there are gaps between the railings. Expert team advised the team to consider the safety of its users during operation by redesigning it.

The general findings from the debriefing session with field experts can be summarised as follows.

- Most of the teams were prepared for the walkthrough of their designs and were ready with good questions to find out operational issues;
- A few teams were not well prepared for the walkthrough of their designs and they did not ask questions on operational issues which crew may face;
- A few teams tried to get the solutions to their design issues from the end users rather than devising a solution to satisfy the end user requirements;
- All field experts identified habitability, maintainability and workability issues within the designs and they suggested possible modifications to overcome them;
- A few teams were focused more on luxury than crew requirements and they were reluctant to alter their designs because they think it is a painful process;

- Most of the teams were not very sure about whether their design solutions met user requirements or not, but they thought their solution may be acceptable;
- All field expert team members experienced enthusiasm in most of the students.

Based on the debriefing session findings and the researcher's observations it was noted that the students highly appreciated the effort taken by the researcher to arrange such workshop to give them a chance to meet the possible end users. It was noted that a few students were not completely engaged in the discussion between field expert and their team. However, most of the students were taking notes during the discussion and most of the teams spent more than one hour with their field expert. Finally all field experts appreciated the effort taken to setting up a common stage to meet seafarers and future maritime designers to share their seafaring experience and knowledge and provide feedback to improve the designs to make a happy ship. In addition they appreciated the effort taken to integrate the HF and HCD knowledge into future maritime designers' education. Apart from the field experts, the design project unit lecturer had not experienced this level of motivated engagement from all design teams prior to this workshop.

3.2 Student feedback forms

There were a total of 50 valid responses received for the feedback forms out of 62 participants.

3.2.1 Students' level of satisfaction about the workshop

The responses for the scaled question was summarised under students' level of satisfaction about the workshop and 92% of the students were satisfied with the workshop and they identified it as a useful event to meet the end users (see Figure 2). 2% of them were identified the workshop as an irrelevant activity and the rest were neutral.

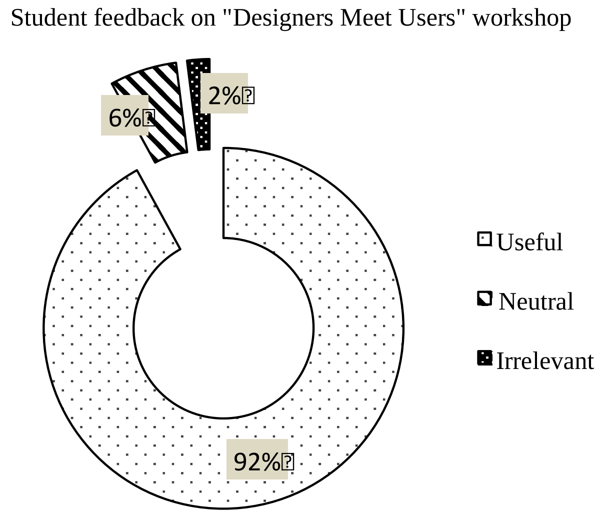


Figure 2. Student feedback on "Designers Meet Users" workshop.

3.2.2 Student suggestions and feedback on the workshop

The responses given to the open-ended question were listed, assigned an explanation and then categorised. A majority of the students provided positive feedback on the workshop as illustrated by a sample of statements listed below, however, 24% did not provide any feedback.

"I think the "designers meet users workshop" was very beneficial, really good to get fresh, experienced eyes, because we don't have that experience though we are designers. This is getting us to think about HCD"
"Constructive feedback was given and advices from users are much appreciated. Gave us insight on stuffs that we may never thought about"
"Consultation time with seafarers was exceptionally valuable. This is the most valuable 60 minutes we spend during this design project period"
"Talking to experts from industry allowed us to visualise potential problems"

Furthermore the majority of students recognised the significance of "post-design" contact with those who work onboard the ships to obtain and maintain a clear understanding about the working conditions, operational issues, physical environment, tasks, work flow and potential hazards on board ships. In addition they identified the importance of end user participation and end user feedback in the maritime design process to provide important information about how ships, their components and services are used, i.e. information that can assist with improving design, operation and usability aspects. Furthermore 88% of students requested to arrange similar workshops again and more often during their design project period. Some of them requested to arrange this workshop in the early stage of the design process, in the first semester of the final year of their studies as illustrated by a few statements listed below.

"We would very much like to have more meetings with users so that designers have a better overview of what users are experiencing with good design and bad designs and we can design based on the user needs"
"Can we have "designers meet user" workshop more often? really helpful. Any possibility to line up meetings with experienced users/experts throughout first semester?"

Some of the students suggested attaching an experienced seafarer as end user representative to each group from the initial stage of the design process as illustrated by a sample of statement below.

"Can we have one end user representative attach to each design team throughout the design process? That will be a great value to us"

Another request from the students was to have slightly longer meetings, for example two hours of Designers Meet User sessions. Three students requested to provide notice of the workshop at least a few weeks prior to allow them to prepare some questions and a short presentation.

4. Discussion

The enthusiasm displayed by of most of the students, and their appreciation of the effort taken to setting up a common stage for seafarers and future designers to meet, so as to incorporate an HCD approach into ship design process, is seen as a clear and positive finding of this study. Most of the teams were well prepared to meet the field experts with their design drawings, specifications and

3D models. This shows the students' interest to discuss their designs with the end users, and thus to obtain their feedback to modify their designs. Since this was the first such workshop arranged at AMC, it was a novelty, and students not only appreciated the opportunity, but also requested to repeat such an event more frequently. Furthermore, the field experts acknowledged the questions raised by the students to clarify the operational aspects onboard the ship and saw them as showing that the students were very motivated to stimulate their knowledge on the operational issues, ships' crew face during their sea time. This feedback and suggestions did help students to learn about good features to be continued and developed, the failures and weaknesses, potential risks and even ideas about how to improve them. In addition, the field expert team highlighted the possible design alterations within the general arrangement and other layout drawing to make the designs more user friendly than its original, indicating that the students had little or no HF knowledge or experience. Thus it is needed to integrate HF/HCD knowledge into maritime design engineering education system in a more targeted engineering-oriented fashion.

However a few teams were not prepared for the workshop session, and some of them requested to be informed about the workshop schedule a few weeks prior to it. In preparation for the next workshop, this will be considered. Furthermore some of the students requested to arrange the workshop in the starting stage of the design project. This has to be considered in future work of this ongoing research study. As students requested, during next design project unit, it will be possible to arrange longer workshops and an end user representative for each project throughout the year. Students could use this approach as an inspiration, to continue this practice during their career, in order to apply an HCD approach during their designs.

The two teams who focused more on luxury for guests were reluctant to rearrange the general arrangement on crew's perspective based on field expert team suggestions because they recognised that modification as a painful process. However the experts showed them the difficulties that crew may face while working onboard the vessel. This finding shows that some designers may be reluctant to apply this HCD approach. Thus it will be necessary to discuss more examples on HCD applications and benefits of HCD approach with future cohorts of maritime design engineering students. In addition it will be needed to arrange more onboard visits to show them the design issues that crew are facing onboard ships. This is supported by the fact that most of the team members were not confident on their design solutions. They posed the question to the field expert team and requested whether their designs satisfy the user and operational requirements. This has to be expected from inexperienced undergraduate students who are doing their first design project and therefore the discussion with the field expert team was a good opportunity for them to gain a worthy experience prior to the start of their career.

5. Conclusion

A "Designers Meet Users" workshop was conducted with Bachelor of Engineering students at Australian Maritime College. A team of seven maritime field experts were present as the end user representatives, to provide HF feedback on final year 'Design Projects'. Students facilitated a walkthrough in their designs to the field experts in order to obtain such feedback and suggestions for improvements. The session was analysed using researchers' observations, student feedback and closed debriefing session with experts. The analysis findings indicate that the students had little or no HF/HCD knowledge or experience, based on the designs they presented. Thus it is necessary to integrate HF/HCD knowledge into maritime design engineering education system.

Based on student feedback, 92% of them acknowledged the value of having such workshops to improve their knowledge by meeting with field experts, and 88% of them requested to repeat it. Also they identified the importance of having discussions with end users during the design stage. It shows that such practical sessions are recognised by the students to improve their knowledge gained through theoretical sessions. Therefore, it is recommended to introduce "Designers Meet Users" workshops for all maritime engineering undergraduate courses. In addition the field expert team appreciated the effort taken by the researchers to provide input to future designers. As the future work, it is intended to arrange such workshops at the different stages of students' final year design projects to maintain the consideration on user needs, through the direct and continuous involvement of end users. This will support future maritime designers to stimulate their knowledge on workplace processes, tasks, equipment, potential risks, and operational issues onboard ships and to establish a clear understanding of the situation in which the design will be used. In addition this effort will encourage future maritime designers to continue this practice during their career, in order to design a happy ship.

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